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The Students' Quiz Series.

CHEMISTRY AND PHYSICS.

A MANUAL FOR STUDENTS AND PRACTITIONERS.

BY

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PREFACE.

In the arrangement of this manual the object has been to collect sufficient material on the sciences of Chemistry and Physics to cover the subjects as taught in a general collegiate or medical course. It is not intended to displace either text-book or lectures, but to be used as an aid by students entering upon the threshold of the sciences, as an auxiliary to lectures, and by teachers in review work. In the preparation of this volume the following authorities have been consulted:—

Roscoe and Schorlemmer's Chemistry;
Fownes' Manual of Chemistry;
Clark's Elements of Chemistry;
Ganot's Physics;
Appleton's Physics;
Draper's Medical Physics;
Richter's Chemie der Kohlenstoffverbindungen;
Beilstein's Handbuch der Organischen Chemie;
U. S. Dispensatory, and others.

Under Organic Chemistry, the atomic weights and specific gravities of the elements are taken from Fownes. The list of atomic weights prepared by F. W. Clarke is the latest accepted authority at date of writing. I am greatly indebted to D. W. Ward, of Columbia College, for the preparation of the section on *Organic Chemistry*, and to Chas. H. Willmarth, of New York, for the section on *Physics*.

JOSEPH STRUTHERS.

NEW YORK, Sept. 1893.

The Editor begs leave to acknowledge much assistance rendered him personally by Chas. H. Willmarth, in editing the sections on *Inorganic and Organic Chemistry*.

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GENERAL INTRODUCTION TO CHEMISTRY AND PHYSICS.

CHEMICAL DEFINITIONS AND GENERAL CONSIDERATIONS.

What is chemistry?

Chemistry is the science which investigates the composition of all substances, together with the combinations and decompositions resulting from their action upon one another under the influence of chemical force.

Material bodies are made up of an unending variety of substances, and chemical science deals with the relations of these substances. In a world consisting of only one substance, the relations of mass and energy which are studied in physics might be observed, but there could be no chemistry. The distinctions of substances are therefore the basis of the science. In most cases the distinctions are obviously striking. No person would confound water, air, iron, and glass; but in many cases it requires close observation and careful study to distinguish differences.

Give the etymology of the word chemistry.

The derivation is from the Greek χημεια (chemeia), meaning "the art of making gold artificially." This term was used by certain writers early in the eleventh century, although at the present time this meaning is referred to the word "alchemy." Some authorities refer the root of the word to *Chemia*, an ancient name for Egypt. Others refer it to Arabic *kimia*, meaning something hidden or secret; and still others refer it to the Celtic word *kheym*, meaning fire.

What is the difference between physical action and chemical action?

Physical action causes merely a change of the *state* of matter and not a change of identity. Chemical action causes a change of the *identity* of the matter itself.

All the phenomena that constantly occur, such as the burning of coal, the freezing of water, the formation of clouds, the explosion of gunpowder, the slaking of lime, etc., are either *chemical* or *physical.* If we heat water, it is changed into an invisible gas; if we cool water, it is changed into the solid we call ice. By cooling this gas or heating the ice we reproduce liquid water. Hence it is evident in this case that we are dealing with but one kind of matter, and the difference of water as a gas, as a liquid, and as a solid, is merely a difference of *state* and not of *composition.* Such a change as this is called physical, and involves a change (*a*) *in form*, as in the flattening of an iron bar, increasing the volume of a substance by the application of heat, etc.; (*b*) *in condition*, as exemplified by water in the state of ice, water, and steam.

In the case of burning coal we observe light, heat, and smoke, and finally the disappearance of the coal with the exception of a little ash. The change here has not only been one of form, from solid to gaseous, but also of molecular identity. We have *destroyed* the original substance and produced other substances from it, and the coal cannot be reproduced from the gases formed. Such a change as this is called *chemical*, and involves a change of the identity of matter.

Give another example of the distinction between physical and chemical change.

This is afforded by mixing yellow sulphur and black iron-filings. As a result, a mixture of a greenish-yellow color is obtained. By examining this mixture with a microscope each particle of iron and sulphur can be identified by sight, and a separation can be made by using a magnet, the particles of iron being gathered up by it, leaving the sulphur, which is not attracted, thus giving us what we started with, iron and sulphur. The change here was one of color, resulting from mixing a yellow substance with a black one; but the iron and sulphur in the mixture are the same as before the mixing. Such a change as this is merely a change in state, a physical change, and such a mixture would be called a *mechanical mixture.*

If these iron and sulphur powders be mixed together, placed in a test-tube, and heat applied, we see a different kind of a change. The sulphur will become soft, pasty, and finally liquid; then the bottom of the mass will begin to glow, getting red-hot. The glow then extends throughout the mixture, even *after* the flame has been removed, and the entire mixture becomes red-hot from heat generated in itself. This is evidently a new kind of phenomenon. On breaking the tube and removing the contents we obtain a homogeneous mass in which we cannot recognize the original particles of yellow sulphur or gray-black iron, nor will the magnet attract the latter. The change here has evidently been one affecting the nature of the substances, and is called a *chemical change.*

How is matter divided?

All matter is divided into two kinds, simple and compound. The simple form of matter is that which cannot be subdivided, and is called elementary matter, or an *element.* Compound matter is made up of elementary substances, and can be divided into the elements which compose it.

State the atomic theory.

Dr. John Dalton, of Manchester, England, in 1808 formulated the atomic theory, which is the foundation of modern chemistry.

He assumed that all matter is made up of indivisible atoms, and that in the chemical union of these atoms, one with another, only *whole* atoms or multiples can unite, *fractions* of atoms being unknown.

What is an atom?

An atom is the smallest particle of matter that can exist in a state of combination. Each atom of an element is identical with every other atom of the same element and differs from the atoms of all other elements.

How do atoms unite?

If hydrogen and oxygen unite chemically, they must do so in proportions representing either the relative weights of their atoms or simple multiples thereof. Similar rules govern the combinations of all the elements. It is assumed, therefore, that the combining weights represent the relative weights of the different atoms compared with hydrogen as unity; that is, an atom of oxygen weighs sixteen times as much as an atom of hydrogen, an atom of sulphur thirty-two times as much, and of nitrogen fourteen times as much, etc. These values are called the *atomic weights* of the elements, a full table of which is given later on. As to the real weights of the atoms we have no definite knowledge, but we are positive concerning the comparative weights.

What is the molecular weight of a compound?

The molecular weight of a compound is the sum of the atomic weights of the atoms which compose the molecule.

What is a molecule of any substance?

Of the given substance it is the smallest particle that can exist and maintain its identity.

What are the three classes of molecules?

(1) Those molecules whose atoms are of the same kind; as all hydrogen, H_2; all oxygen, O_2, etc.

(2) Those molecules whose atoms are of different kinds; as hydrogen and oxygen, H_2O (water); carbon and oxygen, CO_2 (carbon dioxide), etc.

(3) Those molecules whose constituent atoms are alike in kind and proportion, but whose arrangement of the atoms differs. Starch, dex-

trine, and cellulose are compounds differing from one another in properties, although their composition is of the same elements taken in the same quantities.

n times $C_6H_{10}O_5$ represents each of these three compounds.

What is analysis?

It is the method of separating a body into its component parts and of identifying them.

What is synthesis?

It is the method of combining component parts artificially so as to produce the substance under consideration.

For example, water may be divided into the two substances, oxygen and hydrogen, which compose it; or its composition may be determined by causing these gases to unite and proving that by their union water is actually formed.

An almost limitless number of different substances occur in nature, and are made artificially, in which the same component parts are continually repeated in various modes of union. Upon analysis, bodies are finally obtained so simple that they cannot be analyzed further. These simple substances number about seventy, and are called *elements.* All other substances, being necessarily made up of combinations of elements, are called compounds.

The following table contains a list of all the elements now known :—

TABLE OF ATOMIC MASSES.

REVISED BY F. W. CLARKE,

Chief Chemist of the United States Geological Survey.

OCTOBER, 1891.

NAME.	SYMBOL.	ATOMIC MASS.	NAME.	SYMBOL.	ATOMIC MASS.
Aluminium	Al	27.	Neodymium	Nd	140.5
Antimony	Sb	120.	Nickel	Ni	58.7
Arsenic	As	75.	Nitrogen	N	14.03
Barium	Ba	137.	Osmium	Os	190.8
Bismuth	Bi	208.9	Oxygen	O	16.
Boron	B	11.	Palladium	Pd	106.6
Bromine	Br	79.95	Phosphorus	P	31.
Cadmium	Cd	112.	Platinum	Pt	195.
Caesium	Cs	132.9	Potassium	K	39.11
Calcium	Ca	40.	Praseodymium	Pr	143.5
Carbon	C	12.	Rhodium	Rh	103.
Cerium	Ce	140.2	Rubidium	Rb	85.5
Chlorine	Cl	35.45	Ruthenium	Ru	101.6
Chromium	Cr	52.1	Samarium	Sm	150.
Cobalt	Co	59.	Scandium	Sc	44.
Columbium	Cb	94.	Selenium	Se	79.
Copper	Cu	63.6	Silicon	Si	28.4
Erbium	Er	166.3	Silver	Ag	107.92
Fluorine	F	19.	Sodium	Na	23.05
Gadolinium	Gd	156.1	Strontium	Sr	87.6
Gallium	Ga	69.	Sulphur	S	32.06
Germanium	Ge	72.3	Tantalum	Ta	182.6
Glucinum	Gl	9.	Tellurium	Te	125.
Gold	Au	197.3	Terbium	Tb	160.
Hydrogen	H	1.007	Thallium	Tl	204.18
Indium	In	113.7	Thorium	Th	232.6
Iodine	I	126.85	Thulium	Tu	170.7
Iridium	Ir	193.1	Tin	Sn	119.
Iron	Fe	56.	Titanium	Ti	48.
Lanthanum	La	138.2	Tungsten	W	184.
Lead	Pb	206.95	Uranium	U	239.6
Lithium	Li	7.02	Vanadium	V	51.4
Magnesium	Mg	24.3	Ytterbium	Yb	173.
Manganese	Mn	55.	Yttrium	Yt	89.1
Mercury	Hg	200.	Zinc	Zn	65.3
Molybdenum	Mo	96.	Zirconium	Zr	90.6

How is the science of chemistry divided?

Into :
- (*a*) Inorganic
  - non-metallic elements.
  - metallic elements.
- (*b*) Organic
  - compounds of carbon with hydrogen, oxygen, and nitrogen.

What does inorganic chemistry include?

Inorganic chemistry embraces all the elements and their compounds, excepting those compounds of carbon which are set apart for special reasons given hereafter. The division of the elements into metallic and non-metallic is merely one of convenience.

How is the term "metallic" used?

The term *metallic* is used as pertaining to those elements having the properties of a metal, viz., lustre, weight, good conductivity of heat and electricity, ductility, malleability, tenacity, opacity, and to such as are electro-positive. This includes about fifty of the known elements.

How is the term "non-metallic" used?

The term *non-metallic* embraces the rest of the elements, *i. e.*, *hydrogen*, *oxygen*, *nitrogen* (gases at ordinary temperature and pressure); *chlorine*, *bromine*, *iodine*, and *fluorine* (called the haloid group); *sulphur*, *selenium*, and *tellurium* (called the sulphur group); *carbon*, *phosphorus*, *arsenic*, *boron*, and *silicon*.

The line of division is not clearly defined. Some elements, like arsenic, may be fairly put in either class. It is merely a division of convenience, and not fundamentally important.

What does organic chemistry include?

Organic chemistry pertains to the carbon compounds. The division into organic and inorganic chemistry arose from the fact that many of these compounds exist already formed in the bodies of plants and animals.

Organic chemistry is made a special division, not on account of any absolute differences existing between the laws which regulate the formation of substances, but in consequence of the enormous number of compounds of carbon and the peculiar complications so frequently observed in their constitution.

Certain organic substances present a so-called *organized* structure which is directly and essentially the product of vegetable or animal life, and each, in this respect, varies in its mode of formation and constitution from any inorganic compound. The simple cell, the generator of living organisms, exhibits this organized structure. It is impossible to prepare a cell artificially from its elements; but, on the other hand, many liquid or crystalline organic bodies may be built up from their elementary constituents.

The number of carbon compounds already known far exceeds all the compounds of the other elements taken together, and every day is bringing new ones to light. Nearly all of them are formed by the union of different proportions of carbon with one or more of the three other elements, oxygen, hydrogen, and nitrogen.

In what amounts do the elements occur?

The abundance of the elements varies. Their occurrence on the earth's crust is approximately as follows:—

Oxygen . .	46 per cent.	Sodium . .	2 per cent.
Silicon . .	29 "	Potassium .	2 "
Aluminium .	8 "	Calcium . .	4 "
Iron . . .	6 "	The rest . .	1 "
Magnesium .	2 "		100 "

How do the elements vary, and what relation is there between the specific heat and atomic weight of each?

The variation of the elements in their chemical relations is remarkably regular, and seems to be governed by some definite law. If the physical properties of the elements be studied, similar regularities are found; and it is now generally believed, although not as yet fully proved, that all the properties of an element depend in some way upon its atomic weight. For example, the specific heat of an element is inversely proportional to its atomic weight.

Arranging the elements in vertical columns according to the order of their atomic weights, as in the following table, we find that, with the exception of certain metals belonging to the iron and platinum groups, they all arrange themselves in such a manner that the first horizontal line is occupied by the monad elements, the second by the dyads, the third by the triads, etc., as indicated by the composition of the hydrides and oxides in the upper column of the table, where R denotes a metal or hydrogen. Hydrogen itself stands alone, there being no known element intermediate between it and the monad metal lithium. This relation of the elementary bodies, which is called the "periodic law," was first pointed out by Newlands in 1864, and afterwards developed by Odling and Mendelejeff.

ARRANGEMENT OF ELEMENTS IN THE ORDER OF THEIR ATOMIC WEIGHTS.

Series.	Group I. Valency 1. Oxide R_2O.	Group II. Valency 2. Oxide RO.	Group III. Valency 3. Oxide R_2O_3.	Group IV. Valency 4. Oxide RO_2. Hydride RH_4.	Group V. Valency 3–5. Oxide R_2O_5. Hydride RH_3.	Group VI. Valency 2–6. Oxide RO_3. Hydride RH_2.	Group VII. Valency 1–7. Oxide R_2O_7. Hydride RH.	Group VIII. Valency 2–8.
1	H = 1							
2	Li = 7	Be or Gl = 9 —	B = 11 —	C = 12	N = 14 —	O = 16 —	F = 19	
3	Na = 23	Mg = 24	Al = 27.3 —	Si = 28	P = 31 —	S = 32 —	Cl = 35.4	
4	K = 39	— Ca = 40	— Sc = 44	Ti = 48	— V = 51	— Cr = 52,4	— Mn = 55	Fe = 56 Ni = 59 Co = 59
5	— Cu = 63	Zn = 65 —	Ga = 69.8 —	—	As = 75 —	Se = 79 —	Br = 80 —	
6	Rb = 85 —	— Sr = 87	— Y = 89	Zr = 90	— Cb or Nb = 94	— Mo = 95.6	— —	Ru = 103.5 Pd = 106 Rh = 104
7	— Ag = 108	Cd = 111.6 —	In = 113.4 —	Sn = 119	Sb = 122 —	Te = 128 —	I = 126	
8	Cs = 133 —	— Ba = 137	— La = 139	Ce = 141.2	Di = 147 Ta = 182	— W = 184	— —	Os = 199 Ir = 197 Pt = 197
9	— Au = 196	Hg = 200 —	Tl = 204 —	Pb = 206	Bi = 210 —	— —		
10	— —	— —	— —	Th = 231.5		U = 240		

Wherever a blank occurs in the table, some element yet to be discovered probably belongs. Such blanks formerly existed where gallium and scandium are now placed, and from their position Mendelejeff foretold not only their existence, but also their leading properties, long before they were actually discovered.

What is the basis of chemistry?

As before stated, it is the *atom;* then the *molecule*, which is a group of atoms; then *mass*, which is made up of two or more molecules. The molecules of a mass are not in immediate contact with each other. They are held in position by a force, and the minute interstitial spaces are called the physical pores.

What are the forces which act on matter?

1st. *Atomic attraction* (chemism), which is the affinity of the atoms for each other.

2d. *Molecular attraction*, whose subdivisions are:—
  (*a*) Cohesion.
  (*b*) Adhesion.
  (*c*) Polarity.
  (*d*) Repulsion.

3d. *Mass attraction.*

Define—

(*a*) *Cohesion.*—It is the force which unites adjacent molecules of the same nature.

This force is strongly exerted in solids, less so in liquids, and entirely wanting in gases.

Define—

(*b*) *Adhesion.*—It is the force which unites and keeps in contact adjacent surfaces of bodies of different material.

Define—

(*c*) *Polarity.*—It is the force which unites molecules to form crystals.

Define—

(*d*) *Repulsion.*—It is the tendency of molecules to separate from each other, as in gases.

What is mass attraction?

Since mass is an aggregate of two or more molecules, the forces of (a) *cohesion* and (b) *adhesion* are both applicable to the mass. In addition we have *gravitation*, which differs from previous forces in being active at all distances and not interfered with by intervening substances.

Define gravitation.

It is the force by which every particle of matter in the universe is attracted by every other particle. This force varies inversely as the square of the distance and directly as the mass.

What are the three laws of chemical combination?

1st. *Constant proportion.*

The same substance always contains the same elements united in the same proportions.

2d. *Multiple proportion.*

When an element combines with another in several proportions, the higher proportions are always multiples of the first or lowest.

3d. *Equivalents.*

When one element takes the place of another in a combination, the substitution or replacement always takes place in fixed or definite proportions.

The relative quantities of different replaceable elements are called *chemical equivalents* or *equivalent numbers*, and are identical with atomic weights or simple multiples or submultiples of them.

CHEMICAL NOMENCLATURE.

How are the symbols of the elements derived?

Directly from their names or their Latin equivalents; as:—

Name.	Symbol.
Sulphur	S
Carbon	C
Nitrogen	N
Hydrogen	H, etc.

Name.	Latin equivalent.	Symbol.
Iron	Ferrum	Fe
Antimony	Stibium	Sb
Mercury	Hydrargyrum	Hg
Lead	Plumbum	Pb, etc.

How may the number of atoms of an element in a molecule be designated?

By numeral prefixes; as:—

FeO,	MON oxide of iron or iron MON oxide;
MnO_2,	DI oxide of manganese or manganese DI oxide;
SO_3,	TRI oxide of sulphur or sulphur TRI oxide;
Fe_2O_3,	SESQUI oxide of iron or iron SESQUI oxide;
PCl_5,	PENTA chloride of phosphorus or phosphorous PENTA chloride, etc.

No absolute rules can be given for the naming of chemical compounds. The following table has general application :—

	Termination of acid name.	Termination of salt derived from acid.
(1)	——ic acids produce . .	——ate salts.
(2)	——ous " " . .	——ite "
(3)	Hypo——ous acids produce .	Hypo——ite salts.
(4)	Per——ic " " .	Per——ate "

Example.—(1) SulphurIC acid, H_2SO_4, when combined with sodium, Na, produces sodium sulphATE, Na_2SO_4. CarbonIC acid, H_2CO_3, with potassium, K, produces potassium carbonATE, K_2CO_3.

(2) SulphurOUS acid, H_2SO_3, combines with sodium, Na, producing sodium sulphITE; and chlorOUS acid, $HClO_2$, combining with potassium, K, produces potassium chlorITE, $KClO_2$.

(3) The terms HYPO—— and PER—— mean, respectively, "*less than*" and "*more than*," referring to the oxygen contents of the compound. Thus we have the salts :—

$NaClO_3$, sodium chlorATE;
$NaClO_2$, " chlorITE (less O than ——"ATE");
$NaClO$, " HYPO chlorITE (less O than ——"ITE");
$NaClO_4$, " PER chlorATE (more O than ——"ATE").

(4) When there is only one salt of an element, the termination ——IC is used; as, NaCl, sodIC chloride; $CaSO_4$, calcIC sulphate. These salts may also be written sodium chloride, calcium sulphate; or, naming the acid first, chloride of sodium, or sulphate of calcium.

The terminations ——IC and ——OUS, when applied to oxy-acids (that is, acids containing oxygen), show that the combination with oxygen is twofold; ——"OUS" indicating less oxygen than ——"IC;" as :—

SulphurOUS acid	H_2SO_3;
SulphurIC "	H_2SO_4;
PhosphorOUS "	H_3PO_3;
PhosphorIC "	H_3PO_4.

In similar manner, the terminations ——IC and ——OUS, when applied to oxy-salts, show a twofold combination; as—:

FerrOUS sulphate	$FeSo_4$;
FerrIC "	$Fe_2(SO_4)_3$;
MercurOUS chloride . . .	Hg_2Cl_2;
MercurIC " . . .	$HgCl_2$.

In this case ——OUS means relatively more of the *metal* than in the ——IC combination.

The termination ——OUS is sometimes replaced by SUB; as, cuprous oxide, Cu_2O, also suboxide of copper.

(5) The termination ——IDE indicates the *absence of oxygen ;* as, hydrogen sulphIDE, H_2S ; sodium chlorIDE, NaCl ; *except* as applied to oxygen itself ; as, OXIDE ; potassium OXIDE, K_2O ; hydrogen OXIDE, H_2O.

(6) The termination ——IUM or ——UM indicates the element alone ; as, sodIUM, Na ; strontIUM, Sr ; aurUM, Au. The termination ——A indicates the oxide of the element ; as, sodA, Na_2O ; strontiA, SrO ; silicA, SiO_2.

CHEMICAL FORMULÆ.

Give the general considerations regarding them.

Each element is represented by a symbol : H = hydrogen, O = oxygen, etc. ; and in writing chemical formulæ we render the symbols more precise, letting H, for example, represent not only hydrogen in general, but exactly *one unit weight* of hydrogen, or *one unit volume*, or, more definitely still, *one atom*. Thus, O, N, C, etc., represents one atom of each element, respectively ; and 16, 14, 12, etc., means comparative parts by weight. We represent several atoms of an element by numerals written after the symbols and below the line ; as, H, H_2, H_3, H_4, etc., for one, two, three, and four atoms of hydrogen.

Water contains 2 unit weights or two volumes of hydrogen combined with 16 unit weights or one volume of oxygen. Its formula, therefore, is H_2O. The symbols are placed side by side to indicate chemical union. Similarly, hydrogen dioxide is H_2O_2, etc. Perhaps the best examples to cite are the nitrogen compounds, as follows :—

Ammonia	NH_3 ;
Nitrogen mon oxide	N_2O ;
Nitrogen di oxide	N_2O_2, NO ;
Nitrogen tri oxide	N_2O_3 ;
Nitrogen tetr oxide	N_2O_4, NO_2 ;
Nitrogen pent oxide	N_2O_5 ;
Nitrous acid	HNO_2 ;
Nitric acid	HNO_3.

These formulæ almost explain themselves. Take, for example, the last one, as it is the most complicated. It shows, first, that nitric acid contains one atom of hydrogen, one atom of nitrogen, and three atoms of oxygen combined together. Next, that the gases are united by *volume* in the same ratio, 1 : 1 : 3. *By weight* it indicates 1 part of the first element, 14 parts of the second, and (3 times 16) 48 parts of the third. Finally, just as H represents *one atom* of hydrogen, so does HNO_3 represent *one molecule* of nitric acid ; and the sum of the atomic weights, $1 + 14 + 48 = 63$, is called the molecular weight of the compound. If we wish to indicate two or more molecules of nitric acid, we write $2HNO_3$ or $xHNO_3$.

All such formulæ as these may be treated in a somewhat mathematical way, so that chemical reactions may be written out in the form of equations. On one side are written the formulæ of the substances with which the reactions begin, and on the other the formulæ of the substances produced by the change. Since matter is indestructible, the sum of the weights of the atoms on one side of the equation must equal the sum of the weights of the atoms on the other side.

Give examples.

In making oxygen gas by heating chlorate of potassium

$$\begin{array}{lcl}
KClO_3 & = & KCl + O_3 \\
K = 39 & & 39 \\
Cl = 35.5 & & 35.5 + 48 \\
O_3 = \underline{48} & & \\
\quad 122.5 & & \qquad = 122.5.
\end{array}$$

Again, ammonium nitrate, NH_4NO_3, when heated, separates into nitrogen monoxide and water :—

$$\begin{array}{lcllr}
NH_4NO_3 & = & N_2O & + & 2H_2O \\
N = 14 & & N_2 = 28 & & H_2 = 2 \\
H_4 = 4 & & O = \underline{16} & & O = \underline{16} \\
N = 14 & & \qquad 44 & & H_2O = 18 \\
O_3 = \underline{48} & & & & 2H_2O = 36 \\
\quad 80 & & & & 44 + 36 = 80.
\end{array}$$

When sulphuric acid, H_2SO_4, is poured on calcium carbonate (limestone), carbon dioxide gas is given off :—

$$\begin{array}{ccccccccc}
H_2SO_4 & + & CaCO_3 & = & CaSO_4 & + & H_2O & + & CO_2 \\
\left\{\begin{array}{l} H_2 = 2 \\ S = 32 \\ O_4 = \underline{64} \end{array}\right\} & + & \left\{\begin{array}{l} Ca = 40 \\ C = 12 \\ O_3 = \underline{48} \end{array}\right\} & = & \left\{\begin{array}{l} Ca = 40 \\ S = 32 \\ O_4 = \underline{64} \end{array}\right\} & + & \left\{\begin{array}{l} H_2 = 2 \\ O = \underline{16} \end{array}\right\} & = & \left\{\begin{array}{l} C = 12 \\ O_2 = \underline{32} \end{array}\right\} \\
98 & & 100 & & 136 & & 18 & & 44
\end{array}$$

$$98 + 100 = 198 \qquad\qquad 136 + 18 + 44 = 198.$$

What is the utility of these equations?

This class of chemical equations has very great practical utility, as by their use results of reactions can be calculated in advance. For example, suppose we wished to produce a given quantity—a pound, kilogram, or any given *weight*—of hydrogen, and we wished to know just how much material to avoid wasting; the equation is—

$$\begin{array}{lcclc} Zn & + \; H_2SO_4 & = & ZnSO_4 & + \; H_2 \\ Zn = 65 & + \left\{\begin{array}{l} H_2 = \;\;2 \\ S \;\; = 32 \\ O_4 = \underline{64} \end{array}\right\} & = & \left\{\begin{array}{l} Zn = 65 \\ S \;\; = 32 \\ O_4 = \underline{64} \end{array}\right\} & + \; H_2 = 2 \\ & 98 & & 161 & \\ 65 + 98 = 163 & & & 161 + 2 = 163. & \end{array}$$

That is, 65 parts by weight of metallic zinc will unite with 98 parts by weight of sulphuric acid to produce 161 parts by weight of zinc sulphate and 2 parts by weight of hydrogen gas. For "parts by weight" now read "pounds," "ounces," "grains," or "kilograms," as the case may be, and the problem resolves itself into a simple proportion. When a given *volume* of gas is to be produced, its *weight* at 0° C. and 760 mm. pressure is calculated, and the combination by weight ascertained as in the foregoing example. The part of chemistry which deals with these calculations is called *stoichiometry.*

Define valency.

VALENCY, also called "*quantivalence*" or "*atomicity*,"* is the definite capacity which every elementary atom has for uniting with other atoms. If we combine the non-metallic elements, referring to hydrogen as *one*, we have the following :—

I.	II.	III.	IV.
HF	H_2O	H_3N	H_4C
HCl	H_2S	H_3P	H_4Si.
HI	H_2Se	H_3As	
HBr	H_2Te	H_3B	

The elements, thus divided into four groups, are called, respectively, "*monads*" (or those having one bond of affinity; that is, uniting with one atom of hydrogen to produce a saturated compound);

"Dyads," having two bonds uniting with 2 atoms of H;
"Triads," " three " " " 3 " "
"Tetrads," " four " " " 4 " "

Later on we shall meet with "pentads" and "hexads," representing five and six bonds of affinity.

The classification into *even* and *odd* groups is defined by the terms "*artiads*" (all elements having *even* valency) and "*perissads*" (all elements having an *odd* valency).

An element sometimes belongs to more than one group, viz., N may be triad or pentad, but it never has an even valency; and S may be dyad or tetrad, but it never has an odd valency.

---

* The term "atomicity" is also applied to designate the number of atoms in a molecule.

The proportion in which atoms combine together depends on *valency*. Thus, one monad can unite with one monad, one dyad with one dyad or two monads, one triad with one triad, or one monad and one dyad, or with three monads, etc.

The valency is sometimes shown by Roman numerals or more often by simple dashes :—

$Na^{i}Cl^{i}$	$K^{i}Br^{i}$	$Na^{i}I^{i}$	$Ag^{i}Cl^{i}$
$H_2{}^{i}O^{ii}$	$Ag_2{}^{i}O^{ii}$	$Na_2{}^{i}S^{ii}$	$K_2{}^{i}S^{ii}$
$P^{iii}Cl_3{}^{i}$	$As^{iii}Cl_3{}^{i}$	$Sb^{iii}Br_3{}^{i}$	$Bi^{iii}I_3{}^{i}$
$C^{iv}Cl_4{}^{i}$	$C^{iv}Br_4{}^{i}$	$Si^{iv}F_4{}^{i}$	$Si^{iv}I_4{}^{i}$

and

$Ca^{ii}O^{ii}$	$Ba^{ii}S^{ii}$	$Zn^{ii}O^{ii}$	$Hg^{ii}S^{ii}$
$B_2{}^{iii}O_3{}^{ii}$	$N_2{}^{iii}O_3{}^{ii}$	$Sb_2{}^{iii}S_3{}^{ii}$	$Bi_2{}^{iii}S_3{}^{ii}$
$C^{iv}O_2{}^{ii}$	$C^{iv}S_2{}^{ii}$	$Si^{iv}O_2{}^{ii}$	$Si^{iv}S_2{}^{ii}$.

In each case the *valencies* or *bonds* of one element must exactly balance those of the other.

In what other ways may valency be represented?

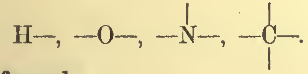
Valency may be represented as follows : Take the combination of C with H, with Cl substitution :—

$$C\left\{\begin{array}{l}H\\H\\H\\H\end{array}\right. \qquad C\left\{\begin{array}{l}Cl\\H\\H\\H\end{array}\right. \qquad C\left\{\begin{array}{l}Cl\\Cl\\H\\H\end{array}\right. \qquad C\left\{\begin{array}{l}Cl\\Cl\\Cl\\H\end{array}\right. \qquad C\left\{\begin{array}{l}Cl\\Cl\\Cl\\Cl.\end{array}\right.$$

Still another method of representing valencies is by dashes, each dash equalling a bond :—

$$\mathrm{H}-,\ \mathrm{O}=,\ \mathrm{N}\equiv,\ \mathrm{C}≣,\ \text{etc.};$$

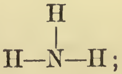
or thus :—



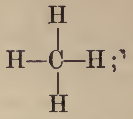
$$\mathrm{H}-,\ -\mathrm{O}-,\ -\overset{|}{\mathrm{N}}-,\ -\underset{|}{\overset{|}{\mathrm{C}}}-.$$

Give examples of formulæ.

From these symbols we derive a system of structural or graphic formulæ, of which the following are good examples :—

Hydrogen in free state . .	H_2	or	$\mathrm{H}-\mathrm{H}$;
Oxygen " " " . .	O_2	"	$\mathrm{O}=\mathrm{O}$;
Nitrogen " " " . .	N_2	"	$\mathrm{N}\equiv\mathrm{N}$;
Water	H_2O	"	$\mathrm{H}-\mathrm{O}-\mathrm{H}$;
Ammonia	NH_3	"	 $\mathrm{H}-\overset{\overset{\mathrm{H}}{|}}{\mathrm{N}}-\mathrm{H}$;

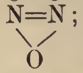
Methane . . . . . CH_4 “



$$H-\overset{H}{\underset{H}{C}}-H;$$

Carbon dioxide . . . CO_2 “ $O=C=O$;

Nitrogen monoxide . . N_2O “



Cyanogen . . . . . C_2N_2 “ $N\equiv C-C\equiv N$;

Nitrogen trioxide . . . N_2O_3 “ $\left\{\begin{array}{l}O=N\\O=N\end{array}\right>O.$

Explain “unsaturated compounds.”

In some cases we have formulæ in which the conditions of valency are not satisfied, as in nitrogen dioxide :—

$$NO \qquad\qquad -N=O,$$

in which one of the valencies or bonds of affinity is unsatisfied. Such a compound is called an “*unsaturated compound.*” These compounds unite with other elements with great ease. In the compound cited, NO, it unites with Cl, forming $Cl-N=O$, in which all bonds are satisfied.

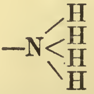
Thus it is that molecules of free hydrogen, nitrogen, oxygen, etc., are regarded as saturated compounds; while the free atoms, if they could exist separately, would be “unsaturated.” In many chemical changes the elementary atoms are probably set free, but they immediately enter into union with each other to form molecules.

Elements when they are made to assume the condition of atoms are said to be in a “*nascent*” state, and as such the chemical activity is greatly increased.

What is a compound radical?

A “*compound radical*” is an unsaturated group of atoms acting like an element; as cyanogen, $-C\equiv N$ CN;

And ammonium,

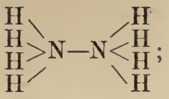


NH_4.

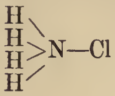
Give examples showing their action.

Chlorine, $Cl-Cl$; cyanogen, $CN-CN$; hydrochloric acid, $H-Cl$; hydrocyanic acid, $H-C\equiv N$; sodium chloride, NaCl; sodium cyanide, $Na-CN$, etc.

Similarly: Ammonium,



and ammonium chloride,



NH_4Cl.

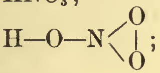
Do structural formulæ represent the relative position of atoms in a molecule?

Structural formulæ are not intended to represent the actual position of the atoms in space, but merely to indicate to the eye the chemical relations of the substances symbolized. By their aid chemical reactions become more easily intelligible, and in many cases compositions and best method of preparation can often be predicted in advance of actual discovery.

When acids are represented graphically they are written on what is called the "*water type;*" that is, one atom of hydrogen in water is replaced with the balance of the atoms required to represent the acid. Thus :—

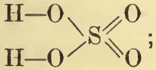
Nitric acid is HNO_3;

Written graphically it becomes



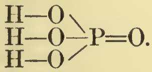
Sulphuric acid is H_2SO_4;

Written graphically is



Phosphoric acid is H_3PO_4;

Written graphically is



How may the formula of an acid be changed to become the formula of a salt?

Knowing that if we replace the hydrogen atom or atoms in an acid a salt is produced, and knowing the valencies of the elements, we are enabled to write a vast number of formulæ which could not possibly be otherwise remembered.

Example.—Write the chemical formula for sulphate of sodium.

——"ic" acid produces ——"ate" salt; hence sulphate of sodium is produced by replacing the hydrogen atoms in sulphuric acid by atoms of sodium: the valency of H is one, of Na is one; hence H_2SO_4 replaced by $Na = Na_2SO_4$.

If a dyad element by taken, as calcium, Ca, then calcium sulphate is $Ca = SO_4$ $CaSO_4$.

In the former case cited, sodium sulphate, still another sulphate may be formed by replacing only one atom of H by Na, yielding a salt, $NaHSO_4$. Such a sulphate is called a *bi* or *acid* sulphate.

Write bisulphate of potash :—

$$H_2{}'SO_4 \quad K' \quad \therefore \quad KHSO_4.$$

Write *normal* sulphate of potash :—

$$H_2{}'SO_4 \quad K' \quad \therefore \quad K_2SO_4.$$

Similarly with carbonic acid, H_2CO_3 :—

Write bicarbonate of sodium :—

$$H_2{}'CO_3 \quad Na' \quad \therefore \quad NaHCO_3.$$

Normal carbonate :—

$$H_2{}'CO_3 \quad Na' \quad \therefore \quad Na_2CO_3, \text{ etc.}$$

Arrange the non-metallic elements according to their valencies.

The non-metallic elements are arranged according to their valencies into the following groups :—

Monads . . . H, Cl, Br, I, F;
Dyads . . . O, S Se, Te;
Triads . . . N, P As, B;
Tetrads . . . Si, C.

PHYSICAL DEFINITIONS AND GENERAL CONSIDERATIONS.

What are the general properties of matter?

1. *Impenetrability:* By which matter occupies space, and by virtue of which nothing else can occupy the same space.

2. *Extension* or *magnitude:* By virtue of which every body occupies a limited portion of space. The shape of that space is called—

3. *Form* or *figure:* Permanent in the case of solids; variable in the case of liquids and gases, the figure of liquids and gases depending on the vessel containing them.

4. *Indestructibility:* By virtue of which matter cannot be destroyed. (Illustrated by the explosion of gunpowder. In this case matter is merely changed from a solid to a gaseous state.)

5. *Divisibility:* By virtue of which matter may be separated into distinct parts. Exemplified as follows: (*a*) The tenth part of a grain of musk will for years fill a room with its odoriferous particles, and at the end of that time will scarcely be diminished in weight; (*b*) Blood is

composed of red, flattened globules, floating in a colorless liquid called *serum.* In man the diameter of one of these globules is less than $\frac{1}{3500}$ inch. The microscope has revealed to us the existence of insects smaller than these particles of blood. If these insects devour still smaller ones in whose veins blood flows, how infinitesimal must be the magnitude of the component globules!

Experiment fails to determine whether there is a limit to the divisibility of matter. Many facts in chemistry, such as the invariability in the relative weights of the elements which combine with each other, would lead us to believe that such a limit does exist. It is on this account that bodies are conceived to be composed of extremely minute and indivisible parts called atoms.

The remaining properties of matter will now be considered, each under its own heading.

What is porosity?

It is the quality by virtue of which interstices or pores exist between the molecules of a body.

What two kinds of pores are there?

Physical, whose interstices are so small that the surrounding molecules remain within the sphere of each other's attracting or repelling forces; and *sensible* or actual cavities, across which molecular forces cannot act. Contraction and expansion, resulting from variations of temperature, are due to the existence of physical pores; while the sensible pores are the seat of exhalation and absorption.

Sensible pores are apparent, viz., sponges, pumice-stone, etc. Physical pores are not apparent; but since all matter may be diminished in volume, we conclude that all matter possesses physical pores.

What is compressibility?

It is the property by virtue of which the volume of a body may be diminished by pressure. This property is a consequence and proof of porosity.

Bodies differ with respect to compressibility. The most compressible are *gases:* they may be compressed in some cases to a few hundredths of the space they occupy at ordinary temperatures. There is generally a limit beyond which pressure reduces them to liquids.

Solids possess less compressibility: cloth, paper, cork, woods, are among the most compressible. Metals are also compressible to some extent, as is shown when a coin receives the impression from the die. There is a limit beyond which, when pressure is increased, bodies are fractured or reduced to powder.

Are liquids compressible?

Experiment has shown them to be very slightly compressible, the degree, however, being so small that it is not easily detected.

What is elasticity?

It is the property by virtue of which bodies resume their original form or volume when the force which altered that form or volume ceases to act.

How may elasticity in solid bodies be developed?

By *pressure*, traction or *pulling*, flexion or *bending*, and by torsion or *twisting*.

Gases and liquids are perfectly elastic; in other words, after undergoing a change in volume they regain exactly their original volume when the pressure is removed.

There is a limit to the elasticity of solids, beyond which they either break or are incapable of regaining their original form. This is called the *limit of elasticity*. Within this limit all substances are perfectly elastic.

In gases and liquids, on the contrary, no such limits can be reached. They always regain their original volume when the original pressure is restored.

What is mobility?

It is the property by virtue of which the position of a body in space may be changed. *Motion* and *rest* may be relative or absolute: by *relative motion* or *rest* of a body we mean its change or permanence of position with respect to surrounding bodies; by its *absolute motion* or *rest* we mean the change or permanence of its position with respect to fixed points in space. Thus a passenger in a railway train may be in a state of relative rest to the train in which he travels; but he is in a state of relative motion with respect to the objects, such as trees, houses, etc., past which the train rushes. These houses, again, enjoy merely a state of relative rest; for the earth itself which bears them is in a state of incessant relative motion with respect to the celestial bodies. In short, absolute motion and rest are unknown to us.

What is inertia?

It is a purely negative though universal property of matter. It is the property that matter cannot of itself change its own state of motion or of rest. If a body is at rest, it remains so until some force acts upon it. If it is in motion, this motion can only be changed by the application of some force. A body when suspended in mid-air does not fall to the earth by virtue of any inherent property, but because it is acted upon by the force of gravity. A billiard-ball gently pushed does not move more and more slowly and finally stop because it has any preference for a state of rest, but because its motion is impeded by the friction on the cloth on which it rolls and by the resistance of the air. If all impeding causes were withdrawn, a body once in motion would continue to move forever in a straight line with unchanging velocity.

What is specific gravity?

It is the ratio of the weight of a body to the weight of an *equal volume* of some other body taken as a unit.

For solids and liquids, the unit generally taken is water at 60° F. For gases, hydrogen is now taken. Formerly air was employed. Air being 14.43 times as heavy as hydrogen, it is easy to transform from one scale to another.

What do the following symbols represent?

D = density or specific gravity.
V = weight of equal volume of unit.
W = weight of substance.

From the definition of specific gravity we derive the following formulæ:—

$$(1)\quad D=\frac{W}{V}\qquad (2)\quad V=\frac{W}{D}\qquad (3)\quad W=DV.$$

What instruments are used for determining the specific gravity of solids and liquids?

The specific gravity of solids and liquids is determined by—

1st. Hydrostatic balance for solids;
2d. Specific gravity flask (called pyknometer) } for liquids.
3d. Hydrometer }

What is the law of Archimedes? State different methods of determining specific gravity of solids.

In determining the specific gravity of solids the law of Archimedes is applied, *i. e.*, that when a body is immersed in a liquid its weight is lessened by the amount which the displaced liquid weighs.

By weighing a substance first in air and then in water, the loss in weight will equal the weight of the displaced water. As this water represents exactly the volume of the substance placed in it, we thus have a ready means of ascertaining the specific gravity of solids.

Example:—

Quartz crystal weighed in air	= 293.7 gms.
" " " " water	= 180.1 "
Difference, being weight of equal volume of water	= 113.6 "

$$\therefore\quad \text{Specific gravity}=\frac{293.7}{113.6}=2.59.$$

Where substances are lighter than water, a weight is generally used as a sinker. The first weighing is of substance alone, next of substance and sinker together in air, then weight of substance and sinker immersed in water. The difference is the weight of the amount of water displaced by both. The substance is then detached, and the weight of sinker is found in air and in water. By making use of these data the specific gravity of substance can be found.

Example:—

Light substance, wax ; weight in air	=133.7	gms.
+sinker of brass	=187.7	"
Both immersed in water weigh	38.8	"
Weight of water equal to bulk of wax + sinker	148.9	"
" of sinker in air	54.	"
" " " water	44.4	"
" of equal bulk of water	9.6	"
" of the bulk of water equal to sinker and wax	148.9	"
" " " " " sinker	9.6	"
" " " " " wax alone	=139.3	"

Now $\frac{133.7}{139.3}=0.9598$, specific gravity of wax.

In case the substance is soluble in water, it is only necessary to employ some liquid having no solvent action and of known specific gravity. A simple calculation gives the weight of a corresponding volume of water, from which can be calculated the specific gravity of the substance.

How is the specific gravity of liquids determined?

(*a*) By pyknometer;
(*b*) By hydrometer.

To determine the specific gravity generally, weigh equal bulks of liquid and water at standard temperature and divide the weight of liquid by the weight of water. The quotient will be greater or less than unity as the liquid experimented with is heavier or lighter than water.

The glass vessel used to measure the volume of a liquid is called a pyknometer. It is of thin glass, having a ground stopper with a flat top, through which is bored a small vertical opening about 1 mm. in diameter. The object of this construction is to facilitate exact measurement. When the vessel is filled with liquid, the stopper is placed in position and the excess of liquid which is forced through the tubular opening is removed by absorption with paper or cloth.

Describe the use of the hydrometer.

If a solid body be immersed in a liquid specifically heavier than itself, it sinks down until it displaces a quantity of liquid equal to its own weight, at which point it floats. A floating body of known specific gravity may thus be used to determine the gravity of solutions by observing the amount that is submerged when placed in the solution. The hydrometer in general use consists of a floating vessel of thin metal or glass, having a weight beneath to maintain it in an upright position and a stem above bearing a divided scale. The liquid to be tested is placed in a small, narrow jar and the instrument floated in it. It is obvious that the denser the liquid the higher will the hydrometer float, because a smaller displacement of liquid will counterbalance its weight. The mark on the stem of the hydrometer at the fluid level is then read off. Instruments of this kind have very extensive use in the arts. They bear different names, according to the kind of liquor for which they are intended. The graduation is often arbitrary, but the principle is the same in all.

Various hydrometers are made: Baumé, Cartier, Sykes, etc.

Other hydrometers are:—

Alcoholometer,
Acidometer,
Salimeter,
Lactometer,
Saccharometer,
Urinometer.

These are used to show whether the different liquids under examination are more or less concentrated, and not to determine exact specific gravity.

What are the two methods in general use for determining specific gravity of gases?

(1) Dumas's method;
(2) Gay Lussac's method.

1. *Dumas:* Finds weight of given volume of gas at known pressure and temperature, and makes comparison with the weight of air or hydrogen direct.

2. *Gay Lussac:* Finds volume occupied by given weight of substance when converted into vapor at a known temperature and pressure, and makes comparison with air or hydrogen under like circumstances.

What are the specific gravities of some of the gases, taking hydrogen as 1?

Specific gravities of a few substances, taking hydrogen as unit:—

Air,	14.43;	CO_2,	22. ;	Cl,	35.5;
N,	14. ;	O_3,	24. ;	I,	127. ;
O,	16. ;	SO_2,	32. ;	Br,	80.

It is readily seen that in the case of most elements in a gaseous state their density is the same as one-half the molecular weight. This is due to the law formulated by Avogadro in 1811, and applies to gases only: Equal volumes of gases under equal temperature and pressure contain equal number of molecules. Hence the density of gases will be directly as their molecular weights; and as their weights are referred to hydrogen as unity (*i. e.*, the *atom* H, and not molecule, which molecule consists of 2 atoms), then the density will always equal one-half the molecular weight. All elements, excepting P, As, Hg, and Cd, contain 2 atoms to a molecule; hence their atomic weights represent the density of elements in a gaseous state.

In case of compounds like CO_2:—

$$C = 12, \quad O = 16 \quad \therefore \quad CO_2 = 12 + 16 + 16 = 44,$$

and the density is 22 times as heavy as hydrogen.

1 litre of H at standard temperature and pressure weighs 0.0896 gm. Hence to find the weight of any volume of any gas, multiply one-half its molecular weight by 0.0896 by the number of litres contained in a given volume; result = weight in gms.

CHEMISTRY.

INORGANIC CHEMISTRY.

THE NON-METALLIC ELEMENTS.

HYDROGEN. Symbol **H.** Atomic weight 1.

What is the origin of the word hydrogen?

It is derived from *hudor*, water, and *genesis*, generation, meaning "water-former." Hydrogen was named by Lavoisier in 1775, although discovered by Cavendish in 1766.

How does hydrogen occur?

It is found FREE in volcanic gases, in natural gas from gas-wells, in meteoric iron (occluded), in the atmosphere of the sun as determined by the spectroscope, and in other self-luminous bodies. It is found COMBINED in water and in an infinite number of organic compounds, such as coal, petroleum, the tissues of plants and animals, etc.

How may hydrogen be prepared?

(1) By decomposing water with metallic sodium;
(2) " " " " an electric current;
(3) " " steam " metallic iron;
(4) " " acids " metals.

Give the formula for each.

(1) $2H_2O + 2Na = 2NaHO + H_2$;
(2) $2H_2O$ dissociated by electricity into $2H_2 + O_2$;
(3) $3H_2O + Fe_2 = F_2O_3 + 3H_2$;
(4) $Zn + H_2SO_4 = ZnSO_4 + H_2$.

What are the physical properties of hydrogen?

In a pure state it is a gas, tasteless, odorless, and colorless. Being the lightest substance known, it is taken as the standard of weight for gases. One litre at 0° C. and 760 mm. pressure weighs 0.0896 gram. This weight is called a *crith.* At a temperature of —140° C. and a pressure of 650 atmospheres, to which hydrogen was subjected by M. Pictet, it becomes liquefied.

What are the chemical properties of hydrogen?

It is an inflammable gas, burning with intense heat and a pale blue flame. One gram of burning hydrogen produces heat sufficient to raise 34,462 grams of water from 0° to 1° C. It is not a poisonous gas, but it does not support respiration. When inhaled it causes the voice to become shrill. Hydrogen burned in the air, thus uniting with the oxygen, forms water: $H_2 + O = H_2O$. It is an effective reducing agent, capable of withdrawing oxygen from its heated compounds. Hydrogen passed over red-hot copper oxide unites with the oxygen, leaving the copper: $CuO + H_2 = Cu + H_2O$.

What are the compounds of hydrogen with oxygen?

There are but two compounds of hydrogen and oxygen. The first is water, H_2O, or hydrogen monoxide; the second is the dioxide of hydrogen, H_2O_2, used for bleaching purposes.

All hydrates contain both oxygen and hydrogen; as, calcium hydrate, $Ca(OH)_2$; sodium hydrate, $NaOH$. The compound radical (OH) is called hydroxyl. Every acid contains hydrogen.

Its important compounds with other elements are with nitrogen, carbon, sulphur, phosphorus, and numerous others.

CHLORINE. Symbol Cl. Atomic weight 35.5.

Give the derivation of its name and its history.

Chlorine was discovered by Scheele in 1774, and named from *chloros*, green, on account of its color.

How does it occur?

It is an abundant element, and is found combined as chlorides in common salt or sodium chloride, chlorides of the alkalies and alkaline earths, in sea-water, and rarer compounds as mineral cerargyrite or silver chloride.

How is it prepared?

By the action of sulphuric acid on common salt and manganese dioxide:—

$$2H_2SO_4 + 2NaCl + MnO_2 = 2(H_2O) + MnSO_4 + Na_2SO_4 + Cl_2;$$

or, by the action of hydrochloric acid upon manganese dioxide:—

$$4(HCl) + MnO_2 = MnCl_2 + 2(H_2O) + Cl_2.$$

What are the physical properties of chlorine?

It is a greenish-yellow gas of intensely suffocating odor, condensing by cold and pressure to a heavy, yellow liquid.

What are its chemical properties?

Under the influence of light it unites directly and violently with hydrogen, producing hydrochloric acid gas. Cold water absorbs two and one-half times its volume of this gas, forming chlorine-water.

When moist it acts as a bleaching agent by seizing the hydrogen of water and liberating the oxygen, which bleaches by direct oxidation. Finely divided copper, antimony, or arsenic placed in the gas combines, evolving heat and light, to produce a chloride. Hydrogen burns freely in chlorine and chlorine in hydrogen.

What are its uses?

It is used as a bleaching agent for linen, cotton, and paper, and as a disinfectant.

What are its important compounds?

With hydrogen it forms hydrochloric acid, HCl; with oxygen it forms oxides, as hypochlorous oxide, Cl_2O; chlorous oxide, Cl_2O_3; and perchloric oxide, Cl_2O_4.

With oxygen and hydrogen it gives rise to several oxy-acids :—

Hypochlorous acid, $HClO$; Chlorous acid, $HClO_2$;
Chloric acid, $HClO_3$; Perchloric acid, $HClO_4$.

With nitrogen: NCl_3; and with carbon: C_2Cl_2, C_2Cl_4, C_2Cl_6.

HYDROCHLORIC ACID, HCl.

What other names are given to hydrochloric acid?

It is often called muriatic acid or chlorhydric acid.

How is it prepared?

It is produced for commerce by treating a chloride with sulphuric acid. Chloride of sodium is generally employed :—

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

What are the physical properties of this acid?

It is a gas very soluble in water, one volume of which at 15° C. will dissolve about 450 volumes of gas, resulting in the liquid acid as it appears in commerce. The pure acid is colorless; the yellowish color often seen is due to impurities of iron.

What are its chemical properties?

It is one of the strongest and most important acids, dissolving many metals with the evolution of hydrogen :—

$$Zn + 2HCl = ZnCl_2 + H_2;$$
$$Fe + 2HCl = FeCl_2 + H_2.$$

What is aqua regia?

It is a mixture of hydrochloric and nitric acids, sometimes termed royal water. It is important on account of its power to dissolve gold and platinum, two metals which resist the action of any single acid. The acids unite, liberating chlorine:—

$$HNO_3 + 3HCl = 2H_2O + NOCl \text{ (nitrosyl chloride)} + Cl_2.$$

How is chlorine applied as a bleaching agent?

Chlorine passed over slaked lime produces chloride of lime or hypochlorite of calcium, one of the most applicable compounds of chlorine for bleaching and disinfecting:—

$$2CaH_2O_2 + 2Cl_2 = CaCl_2O_2 + 2H_2O + CaCl_2.$$

Bleaching powder is a mixture of calcium chloride and hypochlorite of calcium. Exposed to heat, air, and moisture it yields hypochlorous acid ($HClO$), and soon breaks up into water, calcium chlorate, and free chlorine.

How may hydrochloric acid be detected?

Any soluble chloride put with silver nitrate gives a curdy precipitate:—

$$HCl + AgNO_3 = HNO_3 + AgCl;$$
$$NaCl + AgNO_3 = NaNO_3 + AgCl.$$

The oxides of chlorine are all dangerously explosive.

How is hypochlorous acid (HClO) prepared?

It is obtained by passing chlorine gas through water containing calcium carbonate (chalk) in suspension:—

$$Cl_4 + H_2O + CaCO_3 = CaCl_2 + CO_2 + 2HClO.$$

What are its properties?

An aqueous solution has a yellow color, acid taste, and sweet smell. It is a powerful oxidizing and bleaching agent.

Give the preparation and properties of chlorous acid, $HClO_2$.

It is prepared by reducing chloric acid with arsenic trioxide and nitric acid. The result is a greenish-yellow liquid having strong bleaching and oxidizing properties.

Give the method and preparation of chloric acid, $HClO_3$.

It is prepared from barium chlorate and sulphuric acid, or by passing chlorine through a solution of potassium hydrate:—

$$3(Cl_2) + 6KHO = KClO_3 + 5KCl + 3(H_2O).$$

It is the most important of the series. In the concentrated state it is a syrupy liquid resembling nitric acid in many of its properties. It is a powerful oxidizing agent. A drop of it on paper will cause the latter to ignite.

What are its compounds and their uses?

It forms chlorates, among which sodium and potassium chlorates are the most important:—

$$NaClO_3 \text{ and } KClO_2.$$

The latter is used for obtaining oxygen in the laboratory.

It also exists in certain explosive mixtures and is used medicinally.

State the preparation of perchloric acid, $HClO_4$.

It is made by distilling potassium perchlorate with sulphuric acid.

Dropped on wood, paper, or any carbonaceous substance, it combines with explosive violence. In contact with the skin it produces burns.

Give the preparation and properties of nitrogen trichloride, NCl_3.

It is prepared by dissolving chlorine gas in ammonium chloride:—

$$NH_4Cl + 6Cl = NCl_3 + 4HCl.$$

This chloride is a very oily, volatile liquid of extremely explosive nature.

How are the chlorides of carbon obtained?

They are obtained indirectly by the action of chlorine upon organic compounds, as treated in organic chemistry. Chloroform, $CHCl_3$, is the most important.

BROMINE. Symbol **Br**. Atomic weight 79.75.

Give the occurrence of bromine.

Bromine, from *bromos*, a stink, was discovered by Balard in 1826. It is chiefly found in combination, as bromides of sodium and magnesium in sea-water and in mineral springs; also as the mineral embolite, a bromide and chloride of silver.

How is it prepared?

Any bromide heated with sulphuric acid and manganese dioxide furnishes it for the laboratory. Commercially, it is prepared by treating the "mother liquor" of saline solutions, after removing the common salt by crystallization, with sulphuric acid and manganese dioxide, the bromine being distilled and condensed.

What are the physical properties of bromine?

It is a dark red liquid with a suffocating and offensive odor. Excepting mercury, it is the only element which is liquid at ordinary temperatures. Specific gravity 3.187; it freezes at —24.5° C. and boils at 63° C.

What are its chemical properties?

It is slightly soluble in water, more freely so in alcohol, and abundantly so in ether. An aqueous solution, bromine-water, has bleaching properties. It stains organic substances yellow.

Bromine is a commercial product. In 1892 the United States produced 379,480 pounds.

What are its important compounds?

Hydrobromic acid, HBr; Bromic acid, $HBrO_3$;
Hypobromous acid, $HBrO$; Perbromic acid, $HBrO_4$.

How is hydrobromic acid prepared?

Phosphorus and bromine in contact with water produce the acid :—

$$P_2 + Br_6 + 6H_2O = 6HBr + 2H_3PO_3.$$

What are its properties?

It is a colorless, strongly acid gas, of pungent odor, very soluble in water, producing a red solution.

Give the preparation and properties of hypobromous acid.

It is obtained by the action of bromine-water upon mercuric oxide. It is a straw-colored liquid having bleaching properties, and decomposes at 60° C.

State the preparation and properties of bromic acid.

Produced by chlorine gas in bromine-water :—

$$Br_2 + 5Cl_2 + 6H_2O = 2HBrO_3 + 10HCl.$$

Strong acid reaction and bleaching properties; decomposes at 100° C.

How is perbromic acid obtained?

It results from the action of bromine on perchloric acid. The acid is a colorless, oily liquid.

IODINE. Symbol I. Atomic weight 126.53.

When was iodine discovered?

Courtois discovered iodine in 1811.

Where is iodine found?

It exists in marine plants, sea-water, and saline mineral springs, and in deposits of sodium nitrate (Chile saltpetre) in Chile.

How is iodine prepared?

In the laboratory it is made by heating any iodide with sulphuric acid and manganese dioxide :—

$$2KI + 2H_2SO_4 + MnO_2 = K_2SO_4 + MnSO_4 + 2H_2O + I_2.$$

The commercial methods use the ashes of sea-weed for the iodide, which may exist as sodium, potassium, and magnesium iodide.

What are its physical properties?

Bluish-black scales having a metallic lustre; it yields dense violet vapors when heated. Specific gravity 4.95. Melts at 115° C.; boils at 200° C.

What are the chemical properties of iodine?

Practically it is insoluble in water, but easily soluble in alcohol, making the tincture of iodine. It is soluble in potassium iodide solution. With starch it gives a blue color, each being a test for the other.

What are the important compounds of iodine?

They are :—

Hydriodic acid, HI; Iodic acid, HIO_3;
Periodic acid, HIO_4; Pentoxide of iodine, I_2O_5; and
Nitrogen iodide, NI_3.

How is the pentoxide prepared?

It is the result of direct oxidation of iodine.

How is hydriodic acid prepared?

Sulphuretted hydrogen passed through water containing iodine in suspension produces this acid as a heavy, colorless gas within the water. It is used in photography :—

$$2I + H_2S = 2HI + S.$$

Iodic and periodic acids resemble the corresponding compounds of chlorine.

What is nitrogen iodide?

It is formed by the action of ammonium hydrate upon iodine. The slightest touch is sufficient to detonate the compound, NI_3, which separates into N and I_3.

FLUORINE. Symbol **F.** Atomic weight 19.

Give the occurrence of fluorine.

It is a constituent of many minerals, such as fluorite, calcium fluoride, CaF_2; cryolite, sodium and aluminium fluoride, $6NaF,Al_2F_6$; and apatite, $3Ca_3P_2O_8+Ca(Cl,F)_2$. It never occurs free.

Give its properties.

Fluorine is a colorless gas, extremely corrosive, possessing a chemical activity greater than any of the other elements. It is the only element which will not unite with oxygen.

What is its important compound?

It is hydrofluoric acid, HF, prepared from calcium fluoride and sulphuric acid :—

$$CaF_2+H_2SO_4=CaSO_4+2HF.$$

What are its properties?

It is a very volatile liquid, extremely corrosive, uniting violently with water. The dilute acid will attack the silica of glass, and is therefore used for etching small glass articles, like thermometer stems, which could not be readily handled in a sand-blast. It also causes deep ulcers when touched to the skin. It is stored in gutta-percha bottles.

OXYGEN. Symbol **O.** Atomic weight 16.

Give the origin of the name.

It is derived from *oxus*, acid, and *genesis*, generation, meaning acid-former. It was at one time supposed to be the chief element of all acids, therefore erroneously named. Its first name was "dephlogisticated air."

Who discovered oxygen?

It was discovered by Priestley in England, and independently by Scheele in Sweden, in 1744.

Give its occurrence.

It is found FREE as one-fifth of the atmosphere, and in solution in water. COMBINED, it forms by weight about eight-ninths of all water, and occurs in a variety of oxides, acids, and salts. It exists in plant and animal substances, the crust of the earth, and in the sun. It forms about 45 per cent. of the earth's crust.

How may oxygen be prepared?

(1) It is most readily prepared by heating potassium chlorate and collecting the gas by displacement. The decomposition takes place at a

lower temperature if one part of manganese dioxide is added to four parts of potassium chlorate :—

$$2KClO_3 + 2MnO_2 = 2MnO_2 + 2KCl + 3O_2.$$

(2) By heating mercuric oxide :—

$$2HgO = Hg_2 + O_2 \text{ (Priestley's method).}$$

(3) By the decomposition of water by electricity.
(4) By numerous other processes ; as :—

$$3MnO_2 + \text{heat} = Mn_3O_4 + O_2 \text{ (Scheele's method).}$$

What are the physical properties of oxygen ?

It is a colorless, odorless, tasteless gas, liquefiable by cold and pressure. When the pressure is relieved, the heat absorbed by evaporation of part of this liquid serves to solidify the remainder.

What are the chemical properties of oxygen ?

(1) It unites directly with all the elements except fluorine. Its activity in attacking decaying animal and vegetable matter, forming harmless compounds, renders it a great disinfectant and purifier.

(2) It is soluble in water to the extent of 4 per cent. The dissolved oxygen permits life of fishes and other water-breathing animals and purifies the waters on the earth's surface.

(3) It is the supporter of combustion and life. The combustion may be slow, or rapid enough to produce heat and light. The products of all complete combustion of hydrocarbons are CO_2 and H_2O. The readiness with which oxygen unites with wood, coal, petroleum, and other substances furnishes us with heat and light. The blood of all animals contains certain substances which are oxidized through some type of breathing apparatus, the heat of combustion generally serving to elevate the temperature of the body. In this manner the oxygen necessary for animal life is converted into carbon dioxide, CO_2, which is the requisite for plant existence. The plant absorbs the CO_2 through its pores, and by action of sunlight and chlorphyll (the green coloring-matter of plants) the CO_2 is decomposed into carbon and oxygen, the carbon being assimilated by the plant structure and the oxygen returned to the atmosphere.

Oxidation and combustion are carried on very energetically in an atmosphere of oxygen : sulphur and phosphorus burn with intense light, and heated iron or steel wire will burn with sufficient heat to melt the wire.

How are the oxides named ?

(1) They are named monoxide, dioxide, trioxide, tetroxide, pentoxide, and sesquioxide, according to the ratio of oxygen with an element ; as :—

Nitrogen monoxide,	N_2O ;	Nitrogen tetroxide,	N_2O_4 ;
" dioxide,	N_2O_2 ;	" pentoxide,	N_2O_5.
" trioxide,	N_2O_3 ;		

(2) They are also called acid, basic, or neutral, according to the reactions which they have.

What is ozone, O_3 ?

It is oxygen intensified in activity and modified in its nature. It was discovered by Schönbein, of Basle, in 1840.

Where does it occur?

It is found in the air, especially after electric disturbances.

Give its mode of preparation.

(1) It may be prepared by the passage of a current of electricity through a tube containing oxygen;

(2) By slow oxidation of phosphorus, ether, and turpentine :—

$$P_2 + 3O_2 = P_2O_3 + O_3 ;$$

Phosphorus burned in air combines as a pentoxide :—

$$2P_2 + 5O_2 = 2P_2O_5 ;$$

(3) By the action of sulphuric acid on barium dioxide :—

$$3H_2SO_4 + 3BaO_2 = 3BaSO_4 + 3H_2O + O_3.$$

What are the chemical and physical properties of ozone?

It is a gas of peculiar metallic odor, insoluble in water and in solutions of acids or alkalies. By heat it reverts to the less active oxygen. It is a powerful oxidizing agent, corroding cork, rubber, and other organic substances, and rapidly oxidizing iron, silver, and copper, besides possessing potent bleaching and disinfecting properties.

What is the test for ozone?

It decomposes potassium iodide, liberating iodine, which may be detected by starch solution, the iodine turning the solution blue.

How do we know that it exists in air?

There is no direct test for the detection of ozone in air. The potassium iodide test is fallacious, as air contains H_2O_2 and HNO_2, which affect the test. Similarly, the metallic silver test, which is based on the fact that ozone will tarnish silver, cannot be used, as the sulphur compounds existing in air (H_2S) will attack the surface of silver and interfere with the reaction.

By deductions based on experiments of Andrews, who found that the constituent of air which separates iodine from potassium iodide is destroyed by the same reagents which destroy ozone (peroxides), we are led to regard its presence in air as certain and not doubtful.

What is the composition of water?

Water is the monoxide of hydrogen, H_2O. It always contains impurities, either in solution or in suspension, or in both.

What impurities are found in various forms of water?

Rain-water contains gaseous impurities washed from the atmosphere, together with traces of solid matter. River, spring, well, and lake waters contain a variety of mineral substances dissolved from the soil. Sea-water, salt lakes, and mineral springs contain saline substances in large quantities. Effervescent waters are either naturally or artificially charged with carbon dioxide gas, CO_2. Water containing much lime in solution is called "hard" water; if little or no lime is present, the water is said to be "soft." Perfectly pure water is tasteless, and palatable only after aëration. Suspended impurities may be separated from water by filtration; dissolved impurities by distillation.

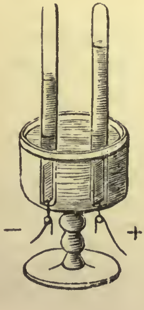
How can water be prepared synthetically?

By passing an electric spark through a mixture of oxygen and hydrogen gas enclosed in a eudiometer, the gases unite to form water. The apparatus consists of a strong glass tube, closed at one end and supported over a trough of mercury, into which the open end projects. It is also adjusted to receive the electric spark. Water is always a product of combustion whenever the substance burned contains hydrogen.

How may water be decomposed?

The two constituent gases of water may be obtained by passing an electric current through a vessel of water and collecting the gases which form and escape from the two poles of the battery.

FIG. 1.



How may the exact proportions be calculated?

Hydrogen is passed over copper oxide contained in a strong glass tube heated to redness. The hydrogen seizes the oxygen of the oxide, forming water and converting the oxide into metallic copper. The weight of the copper oxide before and after the experiment with the weight of the water produced furnishes data for calculations.

What per cent. does the analysis give?

Hydrogen	11.111+	per cent.;
Oxygen	88.889	"
	100.000	"

Practically, there are by weight eight parts of oxygen to one part of hydrogen, or by volume one of oxygen to two of hydrogen.

On what does the commercial analysis of water depend?

Analysis for sanitary and industrial purposes disregards the proportion of oxygen and hydrogen and deals only with dissolved impurities.

Mention some of the salts of ocean water.

The analysis of 1000 grains of water from the British Channel gave the following :—

Water	964.745;
Sodium chloride	27.059;
Potassium chloride	0.766;
Magnesium chloride	3.666;
Magnesium bromide	0.029;
Magnesium sulphate	2.296;
Calcium sulphate	1.406;
Calcium carbonate	0.033;
Traces of iodine and ammoniacal salts	. . .
	100.000.

Classify some of the mineral waters.

(1) *Saline:* Containing sodium chloride (common salt); as the sea, salt springs and lakes; sodium sulphate—Glauber's salt, springs at Ems.

(2) *Alkaline:* Containing bicarbonate of sodium or lithium—Vichy, seltzer, and apollinaris.

(3) *Acid:* Sulphuric and hydrochloric acid, as at Rio Vinagre.

(4) *Acidulous:* Carbonic acid and bicarbonates of lime and magnesium —High Rock Spring, Saratoga.

(5) *Chalybeate:* Iron bicarbonate—Saratoga.

(6) *Alum:* Aluminium and potassium sulphate (alum)—Virginia.

(7) *Borax:* Sodium borate (borax)—California and Italy.

(8) *Sulphur:* Hydrogen sulphide (sulphur spas)—Virginia, Arkansas, and Harrowgate.

(9) *Silicious:* Hot geysers—Iceland and Yellowstone Park; generally alkaline.

Water containing forty grains or less of mineral matter per gallon is termed sweet or fresh. An excess of this amount renders the water a mineral water.

Give an average analysis of Croton water.

Croton water contains the following mineral substances in solution: Parts in 100,000—:

Calcium bicarbonate, $CaH_2(CO_3)_2$	4.53;
Magnesium bicarbonate, $MgH_2(CO_3)_2$	3.25;
Silicon dioxide, SiO_2	1.05;
Sesquioxide of iron, Fe_2O_3	trace;
Sesquioxide of aluminium, Al_2O_3	trace;
Calcium sulphate, $CaSO_4$	0.26;
Sodium sulphate, Na_2SO_4	0.44;
Potassium sulphate, K_2SO_4	0.30;
Sodium chloride, NaCl	0.68;
Organic matter	1.13;
	11.64.

What are the physical properties of water?

Pure water in small quantities is transparent, tasteless, odorless, and colorless. In masses it assumes a bluish tint. It may exist in the solid, liquid, or aëriform state. Ordinarily it freezes at 0° C., boils at 100° C., and evaporates at all temperatures. It is practically incompressible, but contracts regularly from the boiling-point to about 4° C., its maximum density; then expands until 0° C. is reached, at which point it undergoes further and sudden expansion to become ice. It is this expansive force which ruptures water-vessels and water-pipes and disintegrates rocks. Because ice is expanded-water solidified, it is lighter than the same volume of water, and therefore floats. If water had its maximum density at the freezing-point, ice would form at the bottom of rivers and lakes and thus destroy fish and other aquatic life. When vapor is suddenly chilled, snow is formed.

What are the chemical properties of water?

It is the best solvent known, and its solvent power for most solid substances increases with its temperature. For this reason, hot, saturated solutions on cooling deposit their excess of solid matter in the form of crystals.

Water also dissolves gases, but with a power increasing with pressure and a diminution of temperature.

Some solids, like common salt, dissolve equally well in hot or cold water.

How may dissolved gases be freed from water?

(1) By exposure under exhaust pump;
(2) By heating to boiling-point of water;
(3) By freezing the water, thus eliminating the gas. This is shown by the presence of air-bubbles in ice, which consist of the air dissolved from the atmosphere and set free by solidification.

Pure water dissolves gases more copiously than water containing salts in solution, except in some cases where the dissolved salt forms a chemical combination with the gas absorbed.

What standards are based on the properties of water?

(1) *Standard of weight:—*

1 cubic centimetre of water at 4° C. weighs 1 gram.

(2) *Standard of temperature:—*

The Centigrade thermometer has zero-point at temperature of freezing and 100° at temperature of boiling water. Réaumur has zero-point at temperature of freezing and 80° at temperature of boiling. Fahrenheit has 32° at temperature of freezing and 212° at temperature of boiling.

(3) *Standard of amount of heat:—*

The heat-unit is called a caloric.

The French unit is the amount of heat necessary to raise 1 kilogram of water 1° C. The British heat-unit (B. H. U.) is the amount of heat necessary to raise 1 pound of water 1° F.

(4) *Standard of specific gravity:—*

Solids and liquids are referred to water as the unit of comparison.

If the substance is twice as heavy as water, bulk for bulk, its specific gravity is said to be 2, etc.

(5) *Standard of specific heat:—*

The specific heat of water being 1, the specific heat of gases, liquids, and solids is referred to it.

What is the action of water on oxides?

Water acts on many oxides, both basic and acid, with great energy and considerable evolution of heat, producing compounds called "*hydroxides*," which contain hydrogen and oxygen not actually existing as water, the elements undergoing a different arrangement in combining:—

$K_2O + H_2O = 2KOH$, potassium hydroxide (potash);
$CaO + H_2O = CaO_2H_2$, calcium " (slaked lime);
$SO_3 + H_2O = SH_2O_4$, sulphur " (sulphuric acid);
$P_2O_5 + H_2O = 2PHO_3$ phosphorous " (metaphosphoric acid).

In many of these compounds the elements of water are retained with great tenacity, requiring a high temperature to expel them. Calcium hydroxide, for example, requires a red heat to convert it into anhydrous calcium oxide (quicklime), and the hydroxides of potassium, barium, sulphur, and phosphorus cannot be dehydrated by heat alone.

In other cases water appears to combine with substances—salts, for example—without alteration of atomic arrangement. These bodies are called hydrates. This "water" is easily expelled by heat, mostly at 100°–120° C.

What is water of crystallization?

When water combines in the manner mentioned in the preceding paragraph it is called "*water of crystallization.*" This has a great influence on the crystalline form of the substance.

Many salts combine with different quantities of water, according to the temperature at which they separate from solution. Thus: Sodium carbonate, Na_2CO_3, crystallizes from solution at ordinary temperatures in oblique rhombic prisms containing 10 molecules of water, $Na_2CO_3,10H_2O$. Whereas at a higher temperature it crystallizes with 5 or 8 molecules of water, $Na_2CO_3,5H_2O$ or $Na_2CO_3,8H_2O$. From a boiling solution it forms rectangular plates having but 1 molecule of water, Na_2CO_3,H_2O.

What is a cryohydrate?

When these hydrates exist only at temperatures below the freezing-point of water they are called "cryohydrates."

What is efflorescence?

In some cases the water of crystallization is so feebly combined that it gradually separates when the substance containing it is exposed to dry air at ordinary temperatures. This separation is accompanied by loss of crystalline character, the substance falling to powder. This change is called "*efflorescence,*" and is strikingly shown by crystals of alum and ferrous sulphate.

What is deliquescence?

Many substances which are very soluble in water attract water from moist air in such quantities as to form a solution. This change, which is shown by calcium chloride and potassium hydroxide, is called "*deliquescence.*"

Give the formula and history of hydrogen dioxide.

Its formula is H_2O_2. Discovered by Thenard in 1818.

How is hydrogen dioxide prepared?

The action of sulphuric acid on barium dioxide forms hydrogen dioxide:—

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$$

Give the properties of this oxide.

Ordinarily it is a colorless, odorless liquid possessing remarkable bleaching properties. It may be concentrated to a specific gravity of 1.45. Heat easily decomposes it into water and oxygen.

State its use.

It is used as an oxidizing and bleaching agent. It brightens old paintings and whitens the skin and hair.

SULPHUR. Symbol **S.** Atomic weight 32.

How does sulphur occur?

It occurs free in volcanic districts, notably in Sicily and Southern Italy.

It occurs combined as *sulphides* of the common metals—iron, copper, lead, zinc, mercury, silver, arsenic, antimony, etc.

It occurs combined as *sulphates* of calcium (gypsum), barium (barite), strontium (celestite), magnesium (Epsom salts), etc.

It occurs in an unoxidized condition in animal and vegetable tissues.

The volatile oils of garlic, mustard, and horseradish owe their odor to sulphur compounds.

Stains on silverware in contact with eggs, onions, etc., are due to sulphur forming sulphide of silver.

How is sulphur prepared?

(1) If the ore is nearly pure, the sulphur is melted and the earthy matter removed.

(2) When the material contains but little sulphur, it is heated in retorts and the sulphur distilled.

The commercial forms are lump, stick or rolled, and lac sulphur. Lac or milk sulphur is chemically prepared by adding hydrochloric acid to calcium sulphide. It is used medicinally.

What are the physical properties of sulphur?

(1) It is a yellow, brittle, odorless, tasteless solid, capable of allotropic forms. Its atomic weight is 32. Below 500° C. its vapor density is 96; between 800° and 1000° C. its vapor density becomes 32, or normal. Hence at ordinary temperatures the sulphur molecule is S_6, but at high temperatures it becomes S_2. It melts at 114.5° C. and boils at 448° C.

(2) Heated to 230° C. it becomes thick and dark; at 250° C. it regains its fluidity, and if poured into water it assumes a brown color and putty-like consistency. This is known as plastic sulphur, and is much used for taking impressions. This plastic form reverts to ordinary sulphur.

Roll sulphur rubbed with wool or hair excites negative electricity.

(3) The condensed vapors of heated sulphur are known as flowers of sulphur.

Give the chemical properties of sulphur.

Sulphur unites directly with most of the metals by the application of heat, thus making sulphides. It is insoluble in water or alcohol, but soluble in carbon disulphide, benzine, oil of turpentine, heavy petroleum oils, etc.

The compounds of sulphur will now be considered.

HYDROGEN MONOSULPHIDE, H_2S.

(Also called hydrosulphuric acid; sulphydric acid; sulphuretted hydrogen.)

Where does hydrogen monosulphide occur?

It is a frequent product of the putrefaction of organic matter, whether animal or vegetable. It also occurs in certain mineral springs, as at Harrowgate.

How may it be prepared?

Dilute sulphuric acid and iron monosulphide produce hydrogen sulphide:—

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

What are its properties?

It is a colorless gas with an odor like putrid eggs. It is also a powerful narcotic. Burning in oxygen, it gives a blue flame and produces water and sulphur dioxide. It possesses the properties of an acid, and turns blue litmus red.

What are the uses of hydrogen monosulphide?

In the laboratory it is a valuable reagent, precipitating many metals from their solutions and giving characteristics of color, solubility, or other identifying properties.

What is hydrogen persulphide?

HYDROGEN PERSULPHIDE is an unstable compound, supposed to be H_2S_2. It dissolves phosphorus and iodine, forming a phosphorous sulphide and hydrogen iodide respectively, with the evolution of H_2S.

How is sulphur monochloride (SCl or S_2Cl_2) prepared?

It is obtained by passing dry chlorine gas into a retort into which sulphur is sublimed at a red heat. The chloride distils over and is condensed into a mobile, reddish-yellow liquid of disagreeable odor, fuming strongly in air.

It dissolves in carbon disulphide, alcohol, and ether. Ether, when saturated with sulphur at ordinary temperatures, forms a clear, yellow liquid containing 66.7 per cent. of sulphur. The solution of this in crude benzol is used in vulcanizing or sulphurizing caoutchouc.

How is sulphur dichloride prepared?

DICHLORIDE OF SULPHUR, SCl_2, is prepared by passing dry chlorine to saturation into the monochloride cooled by ice and salt, and expelling the excess of chlorine by a stream of carbonic acid gas. It is a deep red liquid. TETRACHLORIDE OF SULPHUR, SCl_4. These two latter chlorides are unimportant.

What are the compounds of sulphur with iodine and bromine?

SULPHUR and BROMINE combine, forming a brownish-red liquid, probably S_2Br_2.

SULPHUR and IODINE form various combinations, the most important of which is S_2I_2, a blackish-gray crystalline mass.

What are the oxides of sulphur?

They are sulphur dioxide and sulphur trioxide:—

$$SO_2 \text{ and } SO_3.$$

Both unite with water and metallic oxides, forming acids and salts.

How is the dioxide of sulphur prepared?

It is prepared either by burning sulphur in the air or in oxygen, or by heating sulphuric acid and copper together. It is the only product of the combustion of sulphur in oxygen.

What are the properties of this oxide?

It is a colorless gas, with the odor of burning sulphur, irrespirable, and a non-supporter of combustion. Sulphur thrown on the fire in stove or grate produces this gas, and thus extinguishes the fire of a burning flue or chimney. Cold water will dissolve thirty times its volume of this gas. It has both bleaching and disinfecting properties. Straw and woollen goods are whitened when subjected to its action. It is also used in the manufacture of sulphuric acid.

How may sulphur trioxide be obtained?

The simplest method for its production is to heat Nordhausen (pyro) sulphuric acid and collect the trioxide as silky, white crystals, which readily dissolve by the absorption of moisture. It also dissolves in water to form sulphuric acid:—

$$H_2S_2O_7 + \text{heat} = H_2SO_4 + SO_3.$$

What are the oxy-acids of sulphur?

(1) Hyposulphurous acid . . . . . H_2SO_2;
(2) Sulphurous acid . . . . . H_2SO_3;
(3) Sulphuric acid . . . . . H_2SO_4;
(4) Pyrosulphuric acid . . . . $H_2S_2O_7$;
(5) Thiosulphuric acid . . . . $H_2S_2O_3$;
(6) Dithionic acid . . . . . $H_2S_2O_6$;
(7) Trithionic acid . . . . . $H_2S_3O_6$;
(8) Tetrathionic acid . . . . $H_2S_4O_6$;
(9) Pentathionic acid . . . . $H_2S_5O_6$.

State the method of preparation and properties of hyposulphurous acid.

It is obtained by the action of zinc and sulphurous acid, and exists as a yellow liquid having reducing and decolorizing properties. Its salts are called *hyposulphites.*

Give the production and properties of sulphurous acid.

Sulphur dioxide united with water gives the acid :—

$$H_2O + SO_2 = H_2SO_3.$$

It has bleaching properties. Its salts are called *sulphites.*

How may sulphuric acid be prepared?

The method employed is to unite sulphur dioxide, nitrogen tetroxide, and water :—

$$SO_2 + H_2O = H_2SO_3;$$
$$H_2SO_3 + NO_2 = H_2SO_4 + NO.$$

Sulphur is burned in a suitable furnace and the SO_2 gas carried to a leaden chamber supplied with steam and air. The SO_2 is absorbed by the condensing vapors. This new compound of sulphurous acid then takes another atom of oxygen, which is furnished by the nitrogen tetroxide, NO_2, which may be produced and admitted to the chamber, forming products shown by the equation. The liquid when drawn off and concentrated by evaporation becomes the sulphuric acid of commerce. The nitrogen tetroxide fumes are produced by the action of sulphuric acid on a nitrate. In place of burning sulphur, iron sulphide is often roasted. Sulphuric acid is often called *oil of vitriol.*

What are the properties of sulphuric acid?

It is a colorless, oily liquid (specific gravity 1.85), intensely acid, and quickly destroying organic matter, which it chars. Boils at 327° C.; freezes at —26° C. With metallic oxides it readily forms sulphates. Attacking the skin, it burns painfully. It decomposes carbonates with effervescence.

What is the test for sulphuric acid?

With barium chloride it forms a white precipitate of insoluble barium sulphate :—

$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl.$$

What is pyrosulphuric acid?

Pyro-, di-, fuming, or Nordhausen sulphuric acid is formed when liquid sulphuric oxide is added to strong sulphuric acid and thus made to yield crystals.

For what is it used?

It is used to dissolve indigo and in the manufacture of artificial alizarin; also for decomposing substances only slightly acted upon by ordinary sulphuric acid.

How is thiosulphuric acid prepared?

This acid is prepared by digesting sulphur with sodium or potassium sulphite and crystallizing the sodium salt :—

$$Na_2SO_3 + S = Na_2S_2O_3.$$

The acid $H_2S_2O_3$ is hardly known except in combination as a salt.

What purpose does the alkaline salt serve?

It is used in photography to dissolve silver chloride; to lixiviate silver ores; also as an "anti-chlor," to remove the lingering traces of chlorine from bleached goods.

The polythionic acids are of theoretical importance only.

SELENIUM. Symbol **Se**. Atomic weight 79.

Where does selenium occur?

Discovered by Berzelius in 1817, it is associated with sulphur in certain rare minerals; also with copper, lead, silver, and mercury.

What are the properties of selenium?

Like sulphur, selenium exists in allotropic forms, and makes several compounds :—

(1) It is a grayish-black solid, insoluble in carbon disulphide;

(2) It is a brick-red powder, soluble in carbon disulphide, from which it crystallizes.

It has but few *uses*, and these are applied in electricity.

Its known *compounds* correspond to those of sulphur. They are not especially important.

TELLURIUM. Symbol **Te.** Atomic weight 125.

Where does tellurium occur?

It is found free; also combined with gold, silver, bismuth, lead, and rare minerals.

What are its properties?

Tellurium is a silvery-white solid, with a clear metallic lustre, burning in the air with a blue flame. It is brittle and a poor conductor of heat and electricity. Its compounds are similar to those of sulphur.

NITROGEN. Symbol **N.** Atomic weight 14.

Give the derivation of the word.

It is derived from *nitron*, nitre, and *geneses*, production. Rutherford discovered it in 1772.

Where does nitrogen occur?

(1) It exists free in the atmosphere, of which it constitutes four-fifths.

(2) Combined, it is found in all animal and plant life and in some of the resultants of their decomposition, such as coal, peat, and lignite; also in ammonia gas emanating from decaying matter.

As mineral nitrates it is abundant, the most important being saltpetre, KNO_3, and Chile saltpetre, $NaNO_3$.

How may nitrogen be obtained?

(1) By exhausting the oxygen from the air by burning phosphorus under a bell-jar held over water. The phosphoric acid thus formed will be dissolved by the water, leaving the nitrogen in the jar:—

$$5(4N_2+O_2)+4P=2P_2O_5+20N_2.$$

(2) By passing air over red-hot copper confined in a suitable vessel. The copper will combine with the oxygen, making copper oxide, and leave the nitrogen in the vessel:—

$$5(4N_2+O_2)+10Cu=10CuO+20N_2.$$

What are the chemical and physical properties of nitrogen?

It is a colorless, tasteless, odorless gas, a non-supporter of combustion, and slightly soluble in water.

Nitrogen is assimilated by plants in the form of ammonia, and as various nitrates and nitrites.

Mention some of the compounds of nitrogen.

Oxides: N_2O, monoxide;
N_2O_2 or NO, dioxide;
N_2O_3, trioxide;

N_2O_4 or NO_2, tetroxide;
N_2O_5, pentoxide.
Acids: HNO, hyponitrous acid;
HNO_2, nitrous acid;
HNO_3, nitric acid.
Salts: Nitrates and nitrites.
Nitrogen and hydrogen, NH_3, ammonia;
Nitrogen and carbon, CN, cyanogen (see Carbon).
Organic compounds (see Organic Chemistry).

Give the preparation of nitrogen monoxide.

This gas, often called nitrous oxide or laughing-gas, is prepared by heating ammonium nitrate and collecting the gas :—

$$NH_4NO_3 + \text{heat} = 2H_2O + N_2O.$$

Give the chemical and physical properties of laughing-gas.

It is a colorless, odorless gas, of sweet taste, liquefiable, and readily soluble in water, forming hyponitrous acid. On account of the ease with which it parts with its oxygen, it supports combustion. Inhaled in small quantities it produces exhilarating effects; hence the name "laughing-gas." Prolonged inhalation produces unconsciousness with complete insensibility to pain. This effect is temporary and not followed by depression.

How is laughing-gas used?

When carefully prepared it is used as an anæsthetic, chiefly by dentists.

How is nitrogen dioxide prepared?

N_2O_2, sometimes written NO, is obtained by the union of nitric acid and copper filings :—

$$8HNO_3 + 3Cu = N_2O_2 + 3Cu(NO_3)_2 + 4H_2O.$$

Give its properties.

It is a colorless, transparent gas, having a suffocating odor. Exposed to the air, it combines with two more atoms of oxygen, forming nitrogen tetroxide. This gas is produced whenever metals are oxidized or dissolved by nitric acid.

How is nitrogen trioxide prepared?

By adding four volumes of N_2O_2 (or NO) to one volume of O and cooling to —18° C., a blue liquid, N_2O_3, is obtained.

What acid does it form?

With water it combines to yield nitrous acid :—

$$N_2O_3 + H_2O = 2HNO_2.$$

How is nitrogen tetroxide obtained?

(*a*) The tetroxide (also called peroxide), N_2O_4 or NO_2, is obtained by heating lead nitrate :—

$$Pb(NO_3)_2 + heat = PbO + O + N_2O_4;$$

The N_2O_4 thus produced is condensed to a *solid* form.

(*b*) By the action of nitric acid on metals the gaseous form is produced.

Give the properties of nitrogen tetroxide.

At very low temperatures it forms colorless prismatic crystals. As a liquid, it has a greenish-yellow tint; as a gas, it is deep red in color.

Give the preparation and properties of nitrogen pentoxide.

The pentoxide or nitric anhydride is obtained by the action of chlorine gas on silver nitrate. It is crystalline and colorless and easily decomposed by water, forming nitric acid :—

$$N_2O_5 + H_2O = 2HNO_3.$$

What is the action of nitrous acid?

It is an unstable, blue liquid, forming nitrites with metals. Its formula is HNO_2.

Where does nitric acid occur?

It is a product of decomposing animal matter containing nitrogen. In the presence of weak alkaline bases, nitrates are formed of these bases. Nitre beds are thus produced, notably as KNO_3, saltpetre in India, and as $NaNO_3$, Chile saltpetre in Chile.

How is nitric acid produced?

Nitric acid is always produced by treating some nitrate, usually sodium or potassium, with sulphuric acid. If much heat is employed, the reaction is :—

$$2NaNO_3 + H_2SO_4 = 2HNO_3 + Na_2SO_4.$$

State the properties of nitric acid.

When pure, it is a colorless liquid with suffocating odor, sour taste, and extremely corrosive tendencies. Specific gravity 1.5. It attacks all ordinary metals except gold and platinum, and thus derives its name "aqua fortis." It turns wool and the skin yellow, oxidizes readily, and forms nitrates with all the regular metals except arsenic and tin.

What use has nitric acid?

Its use is both extensive and important.

(*a*) *Medicinally*, it is used as a caustic and in compounding medicines.

(*b*) *In the arts*, it is used in refining metals, engraving copper plates, and in the production of nitro-glycerine, gun-cotton, aniline dyes, etc.

Why does nitrogen often produce explosive compounds?

Nitrogen is an inert substance, reluctantly entering into combination, and frequently dissociating itself from combination with such readiness as to become dangerous.

Gunpowder is manufactured from charcoal, sulphur, and potassium nitrate. Its explosion produces two expansible gases and smoke of potassium sulphide :—

$$3C + 2KNO_3 + S = 3CO_2 + K_2S + 2N.$$

Where does ammonia occur?

In minute quantities it is found in the air, juices of plants, all mineral waters, and therefore distributed over the earth's surface.

What is its formula?

NH_3.

How is ammonia prepared?

(1) By heating an ammonium salt with an alkaline substance :—

$$2NH_4Cl + Ca(OH)_2 = CaCl_2 + 2NH_3 + 2H_2O\ ;$$

(2) By reducing nitric acid with zinc and caustic potash ;

(3) By putrefactive changes in nature ;

(4) By the destructive distillation of animal and vegetable matter. When illuminating-gas is obtained by distilling coal, ammonia is one of the waste products, and this is the commercial source of the gas.

What are the physical properties of ammonia?

It is a colorless gas, of pungent odor, easily liquefied, for which property it is used in the manufacture of artificial ice, the principle being that when a liquid evaporates heat is absorbed from surrounding objects.

What are its chemical properties?

It is abundantly soluble in water, the aqueous solution being the common aqua ammonia or ammonium hydrate. It is strongly alkaline, neutralizing the strongest acids and forming salts with them. It differs from alkalies in the fact that it will not saponify fats ; it emulsifies them. Ammonia was originally produced near the temple of Ammon, hence the name. It was also obtained by distilling the horns and hoofs of the hart, thus giving rise to the name hartshorn.

What is nitrogen chloride?

NCl_3 is a very volatile vapor, irritating to the eyes. It explodes with fearful violence if brought into contact with almost any combustible material at ordinary temperatures.

What is nitrogen iodide?

Iodine scales saturated with ammonia produce a dry powder, NI_3 or NHI_2, which with the slightest touch gives up its nitrogen explosively.

What is the composition of the atmosphere?

By weight :—		By volume :—	
Nitrogen,	77	Nitrogen,	79.19
Oxygen,	23	Oxygen,	20.81
	100		100.00

It also contains variable quantities of—
Aqueous vapor, depending on the temperature;
Ammonia, traceable;
Solid matter (cosmical and terrestrial dust);
Carbonic dioxide, 3.7 to 6.2 volumes in 10,000 volumes of air.

What is the weight of air?

One litre of pure air at 0° C. and 760 mm. pressure weighs 1.29366 grams, or about 14.42 times as heavy as hydrogen.

Is the air a mixture or a chemical compound?

It is merely a mixture. This is proved as follows:—

1st. The composition is not absolutely constant, as would be the case if it were a chemical compound;

2d. When air is absorbed by water, then expelled, the ratio of the nitrogen and oxygen is not the same as in the original air;

3d. Air produced by mixing proper quantities of oxygen and nitrogen is not attended by any chemical phenomena.

How is the analysis of air made?

Analysis of air is roughly made by passing a given quantity of it over red-hot copper in a combustion-tube and catching the residual gas in an exhaust vessel. The oxygen combining with metallic copper forms copper oxide. The increased weight of the copper in the tube shows the amount of oxygen in the air, and the weight of the residual gas, nitrogen, is readily ascertained.

Another method to ascertain the ratio of oxygen and nitrogen is to pass a given volume of air through some liquid absorbent of oxygen, as pyrogallate of potash. The decrease in volume thus equals the volume of the oxygen, the balance being nitrogen.

PHOSPHORUS. Symbol **P.** Atomic weight 31.

Give the origin of the word.

The word is derived from *phos*, light, and *pherein*, to bear. Phosphorus was discovered by Brandt, in Hamburg, in 1669.

State its occurrence.

In combination as phosphates it occurs in ancient unstratified rocks and modern lava. As a result of their disintegration it occurs in fertile soils, from which it passes into the organisms of plants and ultimately into the bodies of animals subsisting on vegetable life. The composition of human bones is nearly half calcium phosphate, which gives them firmness and inflexibility. The most important mineral is apatite, $Ca(PO_4)_2+\frac{1}{3}Ca(FCl)_2$. It is extensively used as the source of fertilizers. Phosphates of lead, copper, iron, manganese, aluminium, magnesium, and of the rarer elements also occur.

How is phosphorus obtained?

By treating calcium phosphate with sulphuric acid, a precipitate of calcium sulphate and a solution of acid calcium phosphate is obtained. This solution is evaporated to a syrupy consistency, after which carbon is added and the whole subjected to distillation. The phosphorus is reduced and distilled, being caught under water to prevent oxidation.

State the physical properties of phosphorus.

Ordinarily, it exists as a yellowish-white, waxy solid, with the odor of a burning match. Its specific gravity is 1.837. It melts at 44° C. and boils at 290° C., giving a vapor density of 62, which is double its atomic weight, showing that a phosphorus molecule is composed of 4 atoms. Exposed to air at a low temperature it oxidizes slowly, emitting a feeble light, whence its name.

State its chemical properties.

(1) *Ordinary* phosphorus is extremely poisonous. It oxidizes readily, and must therefore be kept under water. It is highly inflammable, and on this account is used in the manufacture of matches. Ignited in contact with the skin, its burns are deep and painful. It is insoluble in water, slightly soluble in olive oil and ether, but freely soluble in carbon disulphide, yielding a dangerous combustible substance.

(2) *Amorphous or allotropic.*—When common phosphorus is heated to 240° C. in an atmosphere free from oxygen, it becomes converted into an extraordinary allotropic form, possessing special properties. It is an odorless, non-luminous, dark red, opaque powder, insoluble, and not poisonous, and has a specific gravity of 2.11. Heated to 260°, it reverts to the ordinary phosphorus.

(3) Bemsen and Keiser have recently described another form, analogous to flowers of sulphur. It is produced by distilling common phosphorus in an atmosphere of hydrogen, which yields a white, flaky substance.

(4) A black variety has also been described by Thénard.

What are the important compounds of phosphorus?

They are oxides, acids, and salts.

How is phosphorous trioxide produced?

It is the product of slow oxidation of phosphorus, and is a white powder, soluble in water, forming phosphorous acid :—

$$2P + 3O_3 = P_2O_3 + O_3;$$
$$P_2O_3 + 3H_2O = 2H_3PO_3.$$

How is phosphorous pentoxide obtained?

It is produced when phosphorus is burned in an excess of air :—

$$2P_2 + 5O_2 = 2P_2O_5.$$

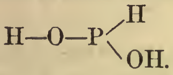
It is a white powder; absorbing water in varying proportions to produce acids :—

$$\begin{array}{ll} P_2O_5 + H_2O = H_2P_2O_6 = 2HPO_3, & \textit{meta}\text{-phosphoric acid;} \\ P_2O_5 + 2H_2O = H_4P_2O_7, & \textit{pyro}\text{-phosphoric acid;} \\ P_2O_5 + 3H_2O = H_6P_2O_8 = 2H_3PO_4, & \textit{ortho}\text{-phosphoric acid.} \end{array}$$

Give two other acids of phosphorus.

Hypophosphorous acid, H_3PO_2; Phosphorous acid, H_3PO_3.

Give the graphic formula for hypophosphorous acid.



How is this acid prepared?

Phosphorus boiled with a solution of lime or baryta yields calcium or barium hypophosphite and phosphuretted hydrogen :—

$$8P + 3Ba(OH)_2 + 6H_2O = 3Ba(PH_2O_2)_2 + 2PH_3.$$

The acid is obtained by heating this hypophosphite with sulphuric acid.

Hypophosphorous acid is a strong oxidizing agent. It forms salts called hypophosphites, several of which are used medicinally.

Although this acid has three hydrogen atoms (see graphic formula), only one is replaceable; therefore it is a monobasic acid.

How is phosphorous acid obtained?

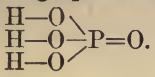
By adding phosphorous trichloride to water, the action produces phosphorous acid and hydrochloric acid :—

$$PCl_3 + 3H_2O = H_3PO_3 + 3HCl.$$

What are its properties?

It is a crystallizable solid, very deliquescent, rapidly absorbing oxygen and passing into phosphoric acid. Its salts are phosphites.

Give the graphic formula for orthophosphoric acid.



How is it prepared?

It may be prepared by several methods :—
(1) By a solution of phosphorous pentoxide in water;
(2) By oxidizing phosphorus with nitric acid;
(3) By phosphorous pentachloride and water :—

$$PCl_5 + 4H_2O = 5HCl + H_3PO_4.$$

What are the properties of H_3PO_4?

It is a very powerful acid, but not poisonous. The aqueous solution evaporated and crystallized gives prismatic crystals. Heated to 160° C., the solution is unchanged; heated to 213° C., it gives up a molecule of water and forms pyrophosphoric acid; heated to a red heat, it gives up another molecule of water and forms metaphosphoric acid.

This orthophosphoric acid gives rise to all the natural phosphates. Other phosphates are artificially prepared.

Give some of the phosphates.

Orthophosphoric acid forms salts called orthophosphates, and on account of being tribasic (having three replaceable hydrogens), it produces three kinds of salts.

With *sodium* in combination these salts are :—

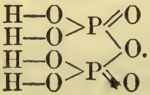
NaH_2PO_4,	monosodium orthophosphate;
Na_2HPO_4,	disodium "
Na_3PO_4,	trisodium "

With *calcium* :—

$CaH_4(PO_4)_2$,	monocalcium orthophosphate;
$Ca_2H_2(PO_4)_2$,	dicalcium "
$Ca_3(PO_4)_2$,	tricalcium "

With *sodium* and *ammonium* a triple salt is produced, called sodium-ammonium hydrogen phosphate, $Na(NH_4)'HPO_4$. It is of great importance in blowpipe analyses, and is known as "salt of phosphorus" or "microcosmic salt."

Give the graphic formula for pyrophosphoric acid.

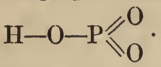


How is pyrophosphoric acid obtained?

By heating orthophosphoric acid.

Heat also produces pyro-*phosphates* from the ortho-*phosphates.*

Give the graphic formula for metaphosphoric acid.



It is often called "glacial phosphoric acid."

How is it prepared?

By heating orthophosphoric acid or pyrophosphoric acid to redness. It is extremely deliquescent, and requires to be kept in closely stoppered bottles. Heat separates a corresponding salt into ammonia, water, and sodium metaphosphate :—

$$Na(NH_4)HPO_4 + heat = NH_3 + H_2O + NaPO_3.$$

How may phosphuretted hydrogen (PH_3) or phosphine be prepared?

It results from boiling water-slaked lime and phosphorus :—

$$6H_2O + 3Ca(OH)_2 + 8P = 2PH_3 + 3CaH_4P_2O_4.$$

This gives phosphine and calcium hypophosphite. It is also prepared by the action of calcium phosphide and water.

What are the properties of phosphine?

It is a colorless gas, having an odor of decayed fish. As usually prepared it is inflammable, on account of the presence of vapors of P_2H_4. When perfectly pure it is not inflammable. It is slightly soluble in water.

Mention some other compounds of phosphorus.

With *chlorine* it forms two compounds: the trichloride, PCl_3, and the pentachloride, PCl_5, of phosphorus; also an oxy-chloride of phosphorus, $POCl_3$. Phosphorus combines with iodine and bromine and gives six compounds with sulphur.

ARSENIC. Symbol As. Atomic weight 75.

How does arsenic occur?

(*a*) *Free*, as mineral native arsenic.
(*b*) *Combined*, as sulphides, As_2S_2, mineral realgar;
As_2S_3, " orpiment.

Also as several arsenides, arsenates, and sulph-arsenides, the most important of which is arsenopyrite, FeAsS.

How is arsenic prepared?

In the laboratory its oxide, As_2O_3, is heated with charcoal in a closed crucible. The arsenic sublimes, and is collected as a brilliant steel-gray, seeming metallic mass.

In commerce, several methods are employed :—

(*a*) By heating the powdered mineral arsenopyrite in long earthen tubes, excluding air, the arsenic is volatilized and collected.

(*b*) By roasting the arsenates of cobalt, iron, and nickel, the arsenic passes off as a trioxide, As_2O_3, which may be purified and reduced by heating with charcoal in a retort.

State the physical properties of arsenic.

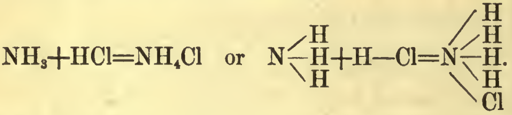
It is a steel-gray, metallic solid, crystalline and brittle. Its specific gravity is 5.7 to 5.9. Its molecule, like one of phosphorus, contains four atoms. Arsenic vapors have the odor of garlic. There is also a black, allotropic form, of specific gravity 4.7.

Mention the chemical properties of arsenic.

It tarnishes in the air and volatilizes without fusion when heated. If air be present, it oxidizes to As_2O_3.

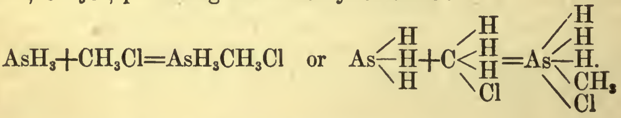
It combines with metals analogously to sulphur and phosphorus.

Like nitrogen, its valency is usually a triad. It is incapable of uniting with more than three atoms of a monad *element*, but its combinations are similar to the reaction of ammonia on hydrochloric acid :—



$$NH_3+HCl=NH_4Cl \quad \text{or} \quad N\begin{cases}H\\H\\H\end{cases}+H-Cl=N\begin{cases}H\\H\\H.\\H\\Cl\end{cases}$$

Arsenuretted hydrogen, AsH_3, unites in the same manner with methyl chloride, CH_3Cl, producing arsen-methyl chloride :—



$$AsH_3+CH_3Cl=AsH_3CH_3Cl \quad \text{or} \quad As\begin{cases}H\\H\\H\end{cases}+C\begin{cases}H\\H\\H\\Cl\end{cases}=As\begin{cases}H\\H\\H.\\CH_3\\Cl\end{cases}$$

State some of the uses of arsenic compounds.

Sodium arsenite is used as a mordant in calico-printing.

A double salt of copper arsenite and copper acetate is known as *Paris green*. This brilliant pigment is used to color wall-paper and to destroy insects. Enormous quantities are consumed in destroying the Colorado potato-beetle.

Arsenite of copper, *Scheele's green*, is used as a pigment. The trioxide, As_2O_3, is used in preparing aniline red and in the manufacture of glass for lamp-shades and ornaments of a milky or opaque appearance.

Medicinally, various solutions are employed.

Give some of the compounds of arsenic.

With hydrogen, AsH_3, arsenuretted hydrogen;
" oxygen, As_2O_3, arsenic trioxide;
" " As_2O_5, " pentoxide;
" sulphur, As_2S_2, As_2S_3, As_2S_5.

How may arsenuretted hydrogen (arsine, AsH_3) be prepared?

It is evolved by the action of zinc and sulphuric acid on any soluble compound of arsenic.

State the properties of arsine.

It is a poisonous, inflammable gas, readily condensing in a black, metallic deposit on cold porcelain or glass held in its flame. This fact constitutes the basis of Marsh's test for arsenic. It is an extremely delicate test, and is used in cases of arsenic-poisoning.

Stibine, SbH_3, gives a similar reaction and black deposit. Their recognition is by reagents.

What precautions must be observed in Marsh's test?

Since both common zinc and sulphuric acid often contain traces of arsenic, their purity should be tested before using.

How is arsenious oxide or arsenic trioxide prepared?

(1) By burning arsenic in the air;
(2) By roasting arsenical minerals.

Give the properties of As_2O_3.

It is a heavy, white, glassy substance, with conchoidal fracture. It is soluble in water, forming arsenious acid:—

$$As_2O_3 + 3H_2O = 2H_3AsO_3.$$

The oxides and acids have a sweet and astringent taste, and are intensely poisonous.

How is arsenic oxide produced?

As_2O_5, arsenic pentoxide, is produced by the action of hot hydrochloric acid on the trioxide and evaporating to dryness.

What are its properties?

It is a white, anhydrous mass, uniting with water to form arsenic acid:—

$$As_2O_5 + 3H_2O = 2H_3AsO_4.$$

This is less poisonous than the arsenious compounds.

How is arsenic disulphide prepared?

As_2S_2 is prepared by heating metallic arsenic with a *proper* proportion of sulphur. It is an orange-red, fusible, volatile solid.

How is arsenic trisulphide prepared?

It may be obtained by heating sulphur and metallic arsenic in proper proportions or by precipitating it from arsenious acid by hydrogen disulphide, thus producing a golden-yellow, fusible, volatile solid.

The pentoxide is unimportant.

BORON. Symbol **B.** Atomic weight 11.

Where does boron occur?

It is found in combination as boric acid, H_3BO_3, and as borax, $Na_2B_2O_7,10H_2O$.

How is boron prepared?

Amorphous boron is produced by heating sodium with boron trioxide. The amorphous form heated with aluminium gives a *crystalline variety.*

What are the properties of boron?

It is allotropic.

The amorphous powder is dark brown.

The crystalline variety is octahedral, specific gravity 2.68, infusible, and nearly as hard as the diamond. It is a triad.

What practical use has boracic acid, H_3BO_3?

(1) Medicinally, it is used as an *antiseptic.*
(2) It is used in blowpipe analyses.
(3) Its main use is for the manufacture of borax.

What are the uses of borax, $Na_2B_2O_7,10H_2O$?

(1) It is a principal reagent in blowpipe analyses.
(2) It is used in making colored glazes and enamels for pottery and porcelain.
(3) It is a flux for cleaning metallic surfaces that are to be brazed or welded.
(4) It is used in the laundry, in bath-water, and for shampooing.

What are the important compounds of boron?

B_2O_3, boric oxide;
H_3BO_3, " acid;
$Na_2B_4O_7,10H_2O$, borax.

With hydrogen as BH_3, a gas resembling NH_3 and PH_3; with halogens as BF_3, a gas, and BCl_3, a volatile liquid; with nitrogen as BN, a brown nitride.

What are the compounds of boric oxide?

Boric oxide unites with water to form *boric acids* and with metallic oxides to form *borates.*

Mention the acids of boron.

$B_2O_3 + H_2O = 2HBO_2$, *meta*-boric acid, non-important;
$2B_2O_3 + H_2O = H_2B_4O_7$, *pyro*-boric acid;
$B_2O_3 + 3H_2O = 2H_3BO_3$, *ortho*-boric acid.

State the occurrence of boric acid, H_3BO_3.

It is a product of the springs of volcanic districts in Tuscany.

Give its mode of preparation.

(1) By concentrating natural spring waters;
(2) By the action of sulphuric acid on borax.

What are the properties of boric acid?

It is antiseptic. In the fused state it dissolves metallic oxides to a limited extent, giving colored beads. It is soluble in water and imparts a green color to flame.

Where does borax occur?

Borax, $Na_2B_4O_7,10H_2O$, or pyroborate of sodium, exists in the lagoon waters of Thibet and in Borax Lake, California.

What properties does borax possess?

It is feebly alkaline in its reaction, and when fused has the power of easily dissolving metallic oxides and imparting distinct colors to beads. This property makes it especially valuable as a blowpipe reagent. Mere traces of a metal will give strong colors. Iron gives yellow to brown; cobalt, blue; nickel, brown; copper, blue; manganese, amethyst; and chromium a green color.

What are the ten molecules of water in the formula?

They are called the water of crystallization. Borax, when first heated, melts in this water; but by continued heat the water is expelled, leaving the anhydrous borax, $Na_2B_4O_7$, called "borax glass."

With sulphuric acid, borax yields scales of boric acid, which are deposited on cooling.

SILICON. Symbol **Si.** Atomic weight 28.

State the occurrence of silicon.

It is always found in combination, and next to oxygen it is the most abundant element, occurring very extensively as SiO_2, quartz or sandstone, and in extensive groups of silicate minerals, such as clays, feldspars, micas, amphibole, pyroxene, serpentine, and slates.

Give the preparation of silicon.

It is obtained by heating the double fluoride of potassium and silicon ($2KF,SiF_4$) with the metal potassium.

Mention its properties.

It is allotropic, existing in three forms :—

(1) A dark brown, lustreless powder;
(2) Needle-shaped crystals harder than glass, fusing at a red heat;
(3) Scaly crystals resembling graphite, but brighter colored and infusible.

How is silicon hydride prepared?

SiH_4, silicon hydride or silica methane, is prepared by the action of hydrochloric acid on any magnesium compound containing silicon. It is a colorless gas, burning with a white flame.

How is silicon tetrachloride prepared?

$SiCl_4$ is formed by the direct combination of its elements or by the action of dry chlorine gas on carbon and silicon oxide, SiO_2. It is a colorless, volatile liquid, which with water yields hydrochloric acid and gelatinous silica. A trichloride, Si_2Cl_6, is also formed.

State the mode of preparing silicon hydro-trichloride.

$SiHCl_3$, silicon hydro-trichloride or silica chloroform, is made by passing dry hydrogen-chloride gas over heated crystallized silicon. It is a very volatile, inflammable liquid, fuming in air. It boils at 34° C.

Compounds are formed with iodine and bromine similar to the chlorides.

What is silicon tetrafluoride?

SiF_4 is formed whenever hydrofluoric acid comes in contact with silica, either free or in combination. It may also be prepared by heating sand with fluorspar and sulphuric acid—

$$SiO_2 + 2CaF_2 + 2H_2SO_4 = SiF_4 + 2CaSO_4 + 2H_2O,$$

and collecting the gas over mercury.

It is colorless, and may be liquefied by cold and pressure.

How is silicofluoric acid prepared?

H_2SiF_6 or $Si_4(HF)_2$, silicofluoric or hydrofluosilicic acid, is obtained when the tetrafluoride, SiF_4, comes in contact with water, silicon hydroxide, and silicic acid. The gelatinous silica is filtered and the filtrate evaporated at a low temperature.

What is silica?

Silica is silicon dioxide, SiO_2, constituting the mineral quartz. It is the only oxide of silicon, and either alone or in combination forms a large proportion of the earth's crust.

What are the properties of silica?

As prepared in the laboratory, it is a fine, white, tasteless powder, specific gravity of 2.66, fusible only in the oxyhydrogen blowpipe or electric furnace. As the crystallized mineral, quartz, it is transparent and generally clear. It is 7 on the scale of hardness.

Enumerate some of the common forms of silica.

Rose quartz, a light rose-colored variety; milky quartz, milk-white; smoky quartz, dark and transparent; numerous massive varieties, as sandstones, chalcedony, jasper, and flint; amethyst, a variety tinged with the oxide of manganese, used for jewelry; hexagonal crystals; also rock crystals, from which "pebble" glasses are cut.

Mention ordinary uses for quartz.

(1) Natural brownstone and sandstone are used for building purposes.
(2) It is a constituent of building mortar.
(3) From it are made fire-brick and hearths for steel and copper furnaces, crucibles, etc.
(4) For industrial purposes, as sand-blasting, manufacture of glass, porcelain, and pottery.

CARBON. Symbol **C**. Atomic weight 12.

State the occurrence of carbon.

It occurs free, as the diamond and graphite (plumbago or black-lead).

Combined, it exists in animal and vegetable life (see Organic Chemistry) and in many kinds of carbonate minerals, the most important of which are:—

Carbonate of iron (siderite)	Used as ores for the production of the metals.
" " copper (malachite)	
" " lead (cerussite)	
" " zinc (smithsonite)	
" " calcium (calcite)	Marbles, used for building and ornamental purposes.
" " " and magnesium (dolomite)	
" " magnesium (magnesite)	(1) Heat-resisting material. (2) Used in the manufacture of Epsom salts, $MgSO_4+7H_2O$.

(See Organic Chemistry, for compounds of carbon and hydrogen.)

The coals, petroleum, and natural gas are compounds of carbon, hydrogen, and oxygen. Carbon and oxygen, CO_2, are found in the atmosphere.

State the preparation of carbon.

It is prepared by the dry distillation of wood. Woody tissue is common cellulose, $C_{18}H_{30}O_{15}$, with minute quantities of coloring-matter and assimilated mineral matter, namely, salts of potassium and sodium, which remain as ash after the charcoal is burned. Wood subjected to heat and protected from the air yields charcoal which is practically pure carbon.

Gas-carbon is formed as a coating in gas-retorts, and is used in the Bunsen galvanic batteries; also for making carbon points for the arc light.

Give the properties of carbon.

Carbon, being allotropic, presents special properties for each form.

Discuss the diamond.

The diamond occurs native in India, South Africa, Borneo, Brazil, and to some extent in the United States. In 1880, Mr. J. B. Hanney, of Glasgow, produced some small diamonds artificially. They were not a commercial success. All diamonds are distinctly crystalline, and owe their brilliancy to their power to refract light. They vary from white to many tints in color. The diamond is the hardest substance known, and is cut and polished by its own powder. When subjected to heat, in the absence of air, it is infusible; but in the oxyhydrogen blowpipe it can be burned into carbon dioxide. It is a bad conductor of electricity. Its specific gravity is 3.48+.

The diamond is used for ornamentation, jewels; for cutting glass; for tipping rock-boring machines, etc., the less valuable kinds being employed for the latter purposes.

Discuss graphite.

Graphite occurs in mines of Siberia, Ceylon, England, California, Vermont, and Ticonderoga, N. Y. It is frequently a product in the manufacture of pig or cast-iron, having been dissolved by the iron and crystallized by cooling, and called "kish." It is black, soft, unctuous, and crystallizes in six-sided plates, of specific gravity 2.25 to 2.27. In solubility and fusibility it resembles the diamond, but it is a good conductor of electricity.

Lead-pencils and stove-polish are made of graphite. This form of carbon is used as a lubricant for machinery, as a paint for metallic material in electrotyping, as a glazing for grains of gunpowder; also as a mould-wash in iron foundries, a wash for iron railings, and, when mixed with clay and sand, as a material for crucibles.

Give a brief account of charcoal.

Charcoal is the result of imperfect combustion of wood. It is black and very porous, the latter property making it an excellent absorbent of gases. One cc. of charcoal properly made will absorb about 18 cc. of oxygen, 68 cc. of carbon dioxide, or 172 cc. of ammonia; hence it may be used as a disinfectant and to absorb noxious gases. It is also a decolorizer. Made from bones instead of wood, it is called *boneblack* or *animal charcoal*, a substance extensively used in sugar refineries for decolorizing sugar. Carbonized blood (blood burned with insufficient air) is used for the same purpose.

The collected smoke (carbon) of burning tar, rosin, turpentine, petroleum, etc., becomes the lampblack of commerce, and is used to make printers' ink, India ink, and black paint.

Wood-charcoal is used in metallurgy, as fuel, and in the manufacture of *crucibles and cementation steel.*

Are the compounds of carbon and hydrogen numerous?

The compounds of carbon and hydrogen already known are exceedingly numerous: perhaps all, in strictness, belong to the domain of organic chemistry, as they cannot, except in very few cases, be formed by the direct union of their elements, but always arise from the decomposition of a complex body of organic origin. A few, however, are here described:—

How is carbon monoxide produced?

Carbon monoxide, CO, commonly called carbonic oxide, is produced when carbon dioxide is passed over incandescent carbon or red-hot metallic iron. One-half of the oxygen of CO_2 is removed and the oxygen is set free, combining with carbon or iron:—

$$CO_2 + C = 2CO \quad \text{or} \quad 3CO_2 + 2Fe = Fe_2O_3 + 3CO.$$

Crystallized oxalic acid decomposed by sulphuric acid produces water, carbon monoxide, and carbon dioxide. These gases are separated by passing them through caustic potash, KOH, which absorbs the dioxide, leaving the monoxide:—

$$H_2C_2O_4 = H_2O + CO_2 + CO.$$

State the properties of CO.

Carbon monoxide is a combustible gas, burning with a pale blue flame, as seen in coal-fires, and producing CO_2. It is colorless, odorless, and extremely poisonous. Its calorific power is 2404.

Mention the use of CO.

It is one of the chief constituents of water-gas. It is also produced in *blast furnaces for iron*, being a principal factor in the reduction of iron from its ores.

Where is carbon dioxide found?

Carbon dioxide, CO_2, or carbonic anhydride, commonly called carbonic acid gas, occurs free in the atmosphere; dissolved in the waters of mineral springs; in "choke-damp" of coal mines, and in mineral carbonates.

How may it be prepared?

(1) By burning carbon with an excess of oxygen;
(2) By decomposing carbonates;
(3) By respiration and fermentation;
(4) By sulphuric or hydrochloric acid and limestone:—

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2.$$

What are the properties of CO_2?

It has a pungent taste and odor and does not support life or combustion. When liquefied by cold and pressure, and a portion of this liquid is allowed to evaporate or escape by a jet, sufficient heat is absorbed to freeze or solidify the portion remaining. In this form it is a white, crystalline, snow-like solid, of a temperature of —78° C.

This gas is soluble in water and other liquids, as exemplified by soda-water, effervescent wines, ale, beer, etc. It is also an important factor in cooking. The fermentation of yeast, the action of baking-powders, and the use of sour milk and a carbonate evolve CO_2 and render bread and cakes light and porous.

What is the test for CO_2?

It renders calcium hydrate or lime-water turbid, forming calcium carbonate and water:—

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

With water, this gas forms carbonic acid, H_2CO_3.

What is cyanogen?

Its formula is C_2N_2 or Cy_2. Carbon and nitrogen do not unite directly, but by passing air over potassium carbonate and charcoal, potassium cyanide, KCN, is obtained; and from it cyanogen may be prepared. The latter is a colorless gas, with an odor suggesting peach-kernels, burning with a beautiful purple flame. By pressure and cold it is easily condensed to a colorless liquid.

Mention some of the compounds of cyanogen.

Cyanogen combines indirectly with hydrogen, forming hydrocyanic acid, HCN, better known as prussic acid. It is extremely poisonous in its character. Other compounds are important as reagents, viz.:—

Potassium cyanide, KCN; Potassium ferrocyanide, $K_4Fe(CN)_6$;
Potassium ferricyanide, $K_6Fe_2(CN)_{12}$.

Cy is often substituted for CN; as K_4FeCy_6, etc.

What is the valency of cyanogen?

The valency of carbon being four and of nitrogen three, the compound CN is unsaturated, and therefore cannot exist in a free state, but must become C_2N_2:—

$$'(C\equiv N) \text{ or } (CN)'; \; (N\equiv C-C\equiv N) \text{ or } C_2N_2.$$

The former is a compound radical. The combinations of cyanogen are cyanides.

State the preparation and properties of carbon disulphide.

Carbon di- or bisulphide is produced by passing the vapors of sulphur over red-hot coals. It is a colorless liquid, of great refractive power, and as commercially prepared it has a nauseous odor, due to impurities. In a pure state its odor suggests ether. It is very combustible:—

$$CO_2 + 2SO_2 = CS_2 + 6O.$$

Its specific gravity is 1.29, and it boils at 46° C.

What special uses has CS_2?

It is a solvent for sulphur, phosphorus, rubber, fats, and oils, and is used also to extract fats from animal matter, as well as to facilitate some of the processes in the manufacture of rubber goods.

THE METALS OR METALLIC ELEMENTS.

What is the difference between metals and non-metals?

Of the *seventy* elements now known, about *fifty* are metals, some of which, however, occur in very small quantities. The line of demarcation between metals and non-metals is not strictly drawn. Their chief differences are of a chemical nature. In general, the oxides of non-metals unite with water to form acids, while those of the metals similarly produce bases. The only acid-forming metallic oxides are those which contain an unusually large proportion of oxygen. Excepting mercury, all metals are solid at ordinary temperatures, and are good conductors of heat and electricity. Many of them are capable of being highly polished and of reflecting light, the latter property giving the so-called metallic lustre. Exclusive of films, like gold-leaf, which will transmit light, all are opaque and usually dense, heavy, ductile, tenacious, and malleable (bismuth and antimony are brittle). They are invariably electro-positive, and in color usually gray or whitish. Calcium, strontium, and gold are yellow; copper a dull red. In hardness there are various grades from liquid mercury to iridium, which will scratch the hardest steel. Their fusibility and specific gravities widely differ, as appears by the following tables:—

SPECIFIC GRAVITY OF SOME METALS.

(F. W. CLARKE.)

NAME.	Sp. gr.	NAME.	Sp. gr.
Aluminium	2.583	Manganese	8.013
Antimony	6.700	Mercury	13.597
Arsenic	5.727	Molybdenum	8.600
Barium	3.750	Nickel	8.900
Bismuth	9.823	Osmium	22.477
Cadmium	8.670	Palladium	12.000
Caesium	1.885	Platinum	21.504
Calcium	1.584	Potassium	0.875
Cerium	6.728	Rhodium	12.100
Chromium	7.300	Rubidium	1.520
Cobalt	8.957	Ruthenium	12.261
Columbium	7.060	Silver	10.512
Copper	8.945	Sodium	0.974
Didymium	6.544	Strontium	2.580
Gallium	5.940	Tantalum	10.780
Glucinum	1.640	Tellurium	6.250
Gold	19.298	Thallium	11.910
Indium	7.421	Thorium	11.230
Iridium	22.421	Tin	7.300
Iron	7.800	Tungsten	19.261
Lanthanum	6.163	Uranium	18.685
Lead	11.335	Vanadium	5.500
Lithium	0.585	Zinc	7.180
Magnesium	1.75	Zirconium	4.15

		Melting-point.
Fusible below a red heat.	Mercury	—39.44° C.
	Gallium	+30.
	Rubidium	38.5.
	Potassium	62.5.
	Sodium	95.6.
	Lithium	180.
	Tin	235.
	Bismuth	270.
	Thallium	294.
	Cadmium	315.
	Lead	334.
	Zinc	423.
	Antimony	425.
	Aluminium	625.

		Melting-point.
Infusible below a red heat.	Silver	1000.
	Copper	1090.
	Gold	1102.
	Cast-iron	1530.
	Pure iron	High forge heat.
	Nickel	
	Cobalt	
	Palladium	1500.
	Molybdenum	Agglomerate, but do not melt in forge.
	Uranium	
	Tungsten	
	Chromium	
	Titanium	Infusible in ordinary blast furnaces. Fusible by oxyhydrogen blowpipe.
	Cerium	
	Osmium	
	Iridium	
	Rhodium	
	Platinum*	
	Tantalum	

Some metals assume a pasty state intermediate between solid and liquid, a property especially valuable in iron and platinum.

Give the classification of metals.

(1) *Metals of the alkalies:* Potassium, sodium, lithium, rubidium, caesium.
(2) *Alkaline earths:* Calcium, strontium, and barium.
(3) *Magnesium group:* Beryllum, magnesium, zinc, and cadmium.
(4) *Lead group:* Lead, thallium.
(5) *Copper group:* Copper, silver, mercury.
(6) *Yttrium group:* Yttrium, erbium, terbium, yterbium, scandium, decipium, lanthanum, cerium, didymium, and samarium.
(7) *Aluminium group:* Aluminium, indium, gallium.
(8) *Iron group:* Manganese, iron, cobalt, nickel.
(9) *Chromium group:* Chromium, molybdenum, tungsten, uranium.
(10) *Tin group:* Tin, titanium, zirconium, thorium.
(11) *Antimony group:* Vanadium, antimony, bismuth, tantalum, niobium.
(12) *Platinum group:* Gold, platinum, palladium, rhodium, iridium, ruthenium, osmium.

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* Platinum melts at 1775° C.

I. METALS OF THE ALKALIES.

State the elements of group I. and their characteristics.

POTASSIUM, SODIUM, CAESIUM, RUBIDIUM, and LITHIUM. They are soft, easily fusible, and volatile at high temperatures. They combine very energetically with oxygen, decompose water at all temperatures, and form strongly basic oxides which are very soluble in water, yielding powerfully caustic and alkaline hydroxides not decomposable by heat. Their carbonates are soluble in water, and each metal forms only one chloride. The hypothetical metal ammonium is usually added to the list of alkali metals, on account of the general similarity of its compounds to those of potassium and sodium.

POTASSIUM. Symbol K. Atomic weight 39.

What is its history?

It was discovered by Sir Humphrey Davy in 1807.

Give the occurrence and modes of preparation of potassium.

Potassium is one of the constituents of granitic minerals, of clay soils and of sea-water. It is prepared by heating to a high temperature potassium monoxide and charcoal in an open retort:—

$$K_2O + C = CO + K_2.$$

The potassium distils and is collected under petroleum, then purified by redistillation. It may also be prepared by decomposing potassium hydrate, KOH, by an electric current.

State its physical properties.

It is a lustrous, silver-white metal, soft at the temperature of the air, plastic, and easily cut with a knife. At 0° C. it is brittle and crystalline.

Give its chemical properties.

Exposed to the air, it rapidly tarnishes on account of the formation of a thin film of oxide; thrown on water, it instantly takes fire, liberating hydrogen and burning with a purple flame. It combines with non-metals, such as chlorine and sulphur, evolving heat and light. As a reducing agent it is valuable in the laboratory.

Discuss potassium chloride.

Potassium chloride, KCl, is found in sea-water and at the Stassfurt deposits in Germany. It reduces to cubic crystals which are soluble in water, and is obtained by heating potassium chlorate:—

$$2KClO_3 + \text{heat} = 2KCl + 3O_2.$$

It is used to prepare other potassium salts, and in an impure state it is employed as a constituent of fertilizers.

State the occurrence and preparation of potassium iodide.

Potassium iodide, KI, occurs in sea-water and is taken up by the seaweeds. It may be prepared by adding iodine to caustic potash—

$$6KOH + 6I = 5KI + 3H_2O + KIO_3,$$

or by reducing iodate of potassium. It exists as white cubic crystals, soluble in water. It is used *medicinally.*

How is potassium bromide prepared?

KBr is prepared by adding bromine to caustic potash. It is found in sea-water and in mineral springs.

It is used in the manufacture of the aniline color eosene, and as a medicine.

What is potassium monoxide?

K_2O, called potassa, is formed by exposing thin slices of metallic potassium to dry air. It is white, deliquescent, and caustic, combining energetically with water to produce potassium hydrate.

What is the nature of potassium tetroxide?

The tetroxide, K_2O_4, is prepared by burning metallic potassium in dry air or oxygen. Thus obtained, it is a deliquescent, chrome-yellow powder, which may be decomposed by water.

What is potassium hydroxide?

Caustic potash or potassium hydrate, KOH, is produced by decomposing potassium carbonate with calcium hydroxide (slaked lime):—

$$K_2CO_3 + CaH_2O_2 = CaCO_3 + 2KHO.$$

The calcium carbonate is precipitated as a powder, and the solution of potassium hydroxide is evaporated to dryness and cast into sticks.

What are the properties of caustic potash?

It is a white solid, very deliquescent, soluble in water and alcohol. Its solution is intensely alkaline, neutralizing the strongest acids and dissolving the skin and other organic matters.

Its chief uses are in the *manufacture of soap* and as a *caustic.*

State the preparation, properties, and use of potassium chlorate, $KClO_3$.

The preparation is simply passing chlorine gas through potassium hydrate or by the action of chloride of potassium on chlorate of calcium:—

$$6KOH + 6Cl = 5KCl + KClO_3 + 3H_2O\,;$$
$$Ca(ClO_3)_2 + 2KCl = 2KClO_3 + CaCl_2.$$

The crystals thus obtained are white and anhydrous, with a taste resembling nitre. They deflagrate violently with combustible matter, and explode by friction or blows.

Medicinally, it is used for allaying *inflammation of the throat;* in the arts, it is employed in making matches, in calico-printing, and as a source of oxygen.

Where does potassium sulphate occur?

Potassium sulphate, K_2SO_4, occurs in the ashes of land and sea plants and in Stassfurt deposits. The residue from nitric acid manufactories is its chief commercial source:—

$$2KNO_3 + H_2SO_4 = 2HNO_3 + K_2SO_4$$

It is a white, crystalline substance, soluble in water.

State the occurrence of potassium nitrate.

Potassium nitrate, KNO_3, often called nitre or saltpetre, is found native in various localities, particularly in India, as an efflorescence of the soil.

How is potassium nitrate prepared?

(1) It is prepared by subjecting animal matter containing nitrogen, wood-ashes, and lime to the action of the air. The nitric acid thus produced unites with the lime and potash to form nitrates. After boiling with water, potassium carbonate is added to decompose the nitrate of lime. The potassium nitrate crystallizes out from the liquid.

(2) By decomposing native sodium nitrate, $NaNO_3$, with K_2CO_3, and potassium chloride, KCl. In Belgium, the refuse K_2CO_3 from the beetroot sugar manufactory is largely employed for this purpose.

What are its properties and uses?

It crystallizes in six-sided prisms, is soluble in water, and is saline and cooling to the taste. When thrown on molten metals rapid oxidation ensues, due to the liberation of oxygen. It is thus used to purify molten gold and silver. Its more extensive use is in the manufacture of gunpowder and in pyrotechnics.

How is potassium carbonate prepared?

Potassium carbonate, K_2CO_3, commercially termed "pearlash," is prepared by evaporating the lye from ashes of plants. It is also obtained from beet-sugar factories, from the Stassfurt deposits, and from the washings of wool.

How is potassium bicarbonate ($KHCO_3$) prepared?

By passing carbon dioxide through a cold solution of potassium carbonate, the bicarbonate is formed.

Name the potassium sulphides.

They are the mono, bi, tri, tetra, and pentasulphide, or K_2S, K_2S_2, K_2S_3, K_2S_4, K_2S_5, and KHS, or the hydrosulphide.

SODIUM. Symbol **Na.** Atomic weight 12.

Mention the properties of sodium.

It is a silver-white metal, soft at common temperatures, readily tarnishing in the air and decomposing water, and igniting the liberated hydrogen if the water be warm. *Its flame is yellow.*

State the occurrence and preparation of sodium chloride, NaCl.

Sodium chloride, or common salt, occurs in many parts of the world in solid beds or irregular strata, as in England, Spain, Germany, United States, and other countries. An inexhaustible supply exists also in the waters of the oceans, and large quantities are obtained from mineral springs.

It is prepared by the evaporation of natural brines and purified by crystallizing.

Give the properties and use of sodium chloride.

It crystallizes in cubes, which are often arranged in pyramidal steps called "*hopper-shaped.*"

It melts at a red heat, volatilizes at high temperatures, and is soluble in about 2½ parts of water. Its solubility is not appreciably increased by heat. It is nearly insoluble in alcohol. It is used as a condiment and food preservative; also in the manufacture of chlorine and hydrochloric acids; as a fertilizer; in glazing earthenware, and as a flux.

How is sodium monoxide prepared?

Sodium monoxide, Na_2O, is produced by oxidizing metallic sodium in dry air or oxygen at a low temperature. It is a white powder, readily absorbing water, thus producing sodium hydroxide:—

$$Na_2O + H_2O = 2NaOH.$$

How is sodium dioxide produced?

Sodium dioxide, Na_2O_2, is formed by oxidizing metallic sodium at 200° C. in a current of dry air. It becomes a white powder, turning yellow by heat.

It may be dissolved and crystallized as $Na_2O_2,8H_2O$. Its solution readily decomposes by heat, forming Na_2O and O.

Give the properties of sodium hydroxide.

Sodium hydroxide, NaOH, is prepared by decomposing a solution of sodium carbonate, Na_2CO_3, with calcium hydroxide, $Ca_2O_2H_2$, in a manner similar to the preparation of potassium hydroxide. It is a white, fusible, deliquescent solid, soluble in water, a powerful alkali, caustic, and a solvent of animal matter. It is used extensively in the manufacture of soap.

What is sodium hypochlorite?

NaOCl, sodium hypochlorite (*eau deLabarraque*), is contained together with the chloride in the bleaching solution. It is prepared by passing chlorine into NaHO.

How is sodium chlorate prepared?

$NaClO_3$, sodium chlorate, is produced from sodium carbonate and chloric acid. It is used in calico-printing and in the manufacture of aniline black.

How is sodium sulphate prepared?

Sodium sulphate, $Na_2SO_4,10H_2O$, is a product of many chemical operations. It is crystalline and efflorescent, possessing a bitter taste. Medicinally, it is used as a purgative, and is known as *Glauber's salts.*

State the preparation and use of sodium thiosulphate.

$Na_2S_2O_3$, sodium thiosulphate, formerly called *hyposulphite*, is prepared from Na_2SO_3 by the addition of sulphur. It is used in *photography* to dissolve unaltered silver chloride; in *paper manufacture* as "anti-chlor;" and in *lixiviating* silver ores.

Give the occurrence, mode of preparation, and use of sodium nitrate.

$NaNO_3$, sodium nitrate, *cubic nitre*, or *Chile saltpetre*, occurs native in enormous quantity at Tarapaca Peru (Chile). It is deliquescent, very soluble in water, and is used—

(1) In the manufacture of nitric acid,
(2) In the preparation of potassium nitrate;
(3) As a top dresser in fertilizing.

It cannot be used for gunpowder, as the mixture burns too slowly and becomes damp in the air.

Mention the phosphates of sodium.

The PHOSPHATES OF SODIUM are:—

Hydro-di-sodic-phosphate,	$Na_2HPO_4,12H_2O$;
Tri-sodic-orthophosphate,	$Na_3PO_4,12H_2O$;
Mono-sodic-orthophosphate,	NaH_2PO_4,H_2O;
Normal pyrophosphate,	$Na_4P_2O_7,10H_2O$;
Acid pyrophosphate,	$Na_2H_2P_2O_7$;
Metaphosphates,	$nNaPO_3$.

$n = 1, 2, 3$, etc., called mono, di, tri, etc.

What are the arsenates of sodium?

The ARSENATES OF SODIUM resemble the phosphates. An impure sodium arsenate is largely used in calico-printing and in clearing cloth after mordanting.

What is sodium pyroborate?

$Na_2B_4O_7,10H_2O$, sodium pyroborate, is BORAX (see under *Boron*).

Give the silicates of sodium.

METASILICATE, Na_2SiO_3 or Na_2O,SiO_2;
QUADRISILICATE, $Na_2Si_4O_9$ or $Na_2O,4SiO_2$.

Both are prepared by fusing together Na_2CO_3 and SiO_2 in proper amounts.

What is the quadrisilicate of sodium?

The quadrisilicate, $Na_2Si_4O_9$, is known as *soluble glass*, as it dissolves in water. It has extensive uses, as follows:—

(1) In the manufacture of artificial stone;
(2) In cement;
(3) In the manufacture of silicate soap.

How is sodium carbonate prepared?

$Na_2CO_3,10H_2O$, normal sodium carbonate, was formerly prepared from ashes of sea-weeds and of plants which grow by the sea-side. It is now manufactured on a large scale from common salt. The most important processes are Leblanc's and the ammonia-soda process. The former process consists, first, in the decomposition of NaCl by H_2SO_4, yielding HCl and Na_2SO_4, called "*salt-cake;*" then in mixing the salt-cake with chalk and coal and heating to fusion in a reverberatory furnace. The crude product is called "*black-ash*" or "*ball soda.*" This is purified, and is the *soda-ash* of commerce, and contains from 48 to 52 per cent. of Na_2O. This commercial product can be further purified by solution and crystallization.

The ammonia-soda process consists in decomposing a solution of NaCl with ammonium carbonate, whereby the greater part of the sodium is precipitated as bicarbonate, while the ammonia remains in solution as ammonium chloride. This latter salt is heated with lime to liberate ammonia, which is then reconverted into bicarbonate by the carbonic acid evolved in the conversion of the sodium bicarbonate into monocarbonate by heat; and the ammonium bicarbonate thus reproduced is employed to decompose fresh portions of sodium chloride, so that the process is made continuous.

Mention the properties of sodium carbonate.

The ordinary monoclinic crystals contain 10 molecules of water of crystallization, but it may be made to crystallize with varying amounts.

It is efflorescent in dry air, very soluble in water, has a strong, disagreeable alkaline taste, and a powerful alkaline reaction.

Give the preparation, properties, and use of sodium bicarbonate.

$NaHCO_3$, bicarbonate of sodium or acid carbonate of sodium, is prepared by passing CO_2 gas into a cold solution of Na_2CO_3. It is a crystalline, white powder, soluble in 10 to 15 parts of water, and feebly alkaline. It is used in baking-powder.

Give the tests for sodium compounds.

(1) All the salts, except antimonate, are soluble in water.
(2) Antimonate of potassium throws down a *white* precipitate of sodium antimonate, providing the solution has been previously freed from all bases except the alkalies.
(3) It tinges flame *yellow*.
(4) Their spectrum shows a bright line in the yellow band.

LITHIUM (*lithos*, a stone). Symbol **Li.** Atomic weight 7.

Give the occurrence, preparation, and tests for lithium.

Lithium occurs in the minerals lepidolite and petalite, and in small quantities in mineral springs. It is obtained by decomposing the fused chloride by electrolysis. Like sodium, it is a white metal, easily oxidized. It is the lightest solid known. Lithia or lithium hydrate, LiOH, is much less soluble than potassium or sodium hydrate. It forms salts with carbonic, hydrochloric, sulphuric, and phosphoric acids. The salts of lithium color the outer flame of the blowpipe carmine-red, and the spectrum presents one bright red line, by means of which the minutest trace of lithium may be detected.

CAESIUM and **RUBIDIUM.** Atomic weights 133 and 85.4.

Symbols **Cs.** and **Rb.**

Where are caesium and rubidium found?

Both are widely diffused in nature, but in very small amounts in minerals and mineral waters. The mineral lepidolite has been found to contain as much as 0.2 per cent. of rubidium. These rare elements form many salts. The hydroxides are powerful bases. Like potassium, they are soft at ordinary temperatures and easily oxidized. They take fire when thrown on water.

State some facts regarding ammonium.

AMMONIUM, NH_4, is a compound radical. Its salts are most conveniently studied in this place on account of their close analogy to K and

Na. These salts are formed by the direct union of ammonia, NH_3, with acids; as:—

$$NH_3 + HCl = NH_4Cl;$$
$$NH_3 + HNO_3 = NH_4(NO_3);$$
$$2NH_3 + H_2SO_4 = (NH_4)_2SO_4.$$

The radical NH_4, in its free state, is a dark blue liquid, existing only under very high pressure. At a low temperature it readily decomposes into NH_3 and H.

Give the preparation and properties of ammonium chloride.

NH_4Cl, ammonium chloride or sal-ammoniac, is prepared from the ammoniacal liquor of gas-works and from condensed products in the manufacture of boneblack. It forms anhydrous crystals having a sharp, saline taste, is soluble in cold water, and sublimes without decomposition.

Give the preparation and use of ammonium sulphate.

$(NH_4)_2SO_4$, ammonium sulphate, is prepared by adding H_2SO_4 in excess to the coal-gas liquor just mentioned and purifying the product. The crystals are white and very soluble in water. It is much employed as a fertilizer and for the manufacture of alum.

How is ammonium nitrate produced?

NH_4NO_3, ammonium nitrate, is obtained by adding nitric acid to ammonium carbonate and crystallizing the product. The crystals are white, six-sided prisms, slightly deliquescent, soluble in 2 parts of cold water, producing considerable depression of temperature; when heated above 230° C. they are decomposed into water and nitrous oxide gas:—

$$NH_4NO_3 + \text{heat} = 2H_2O + N_2O.$$

Give the phosphates of ammonium.

Normal or triammonic salt $(NH_4)_3PO_4$; sodium ammonium hydrogen phosphate (*phosphorous salt; microcosmic salt*), $NaNH_4HPO,4H_2O$. The latter is valuable as a flux in blowpipe experiments.

How is ammonium carbonate obtained?

$(NH_4)_2CO_3$, normal ammonium carbonate, is obtained by subliming chloride of ammonium and calcium carbonate:—

$$2NH_4Cl + CaCo_3 = (NH_4)_2CO_3 + CaCl_2.$$

It is an unstable compound, decomposing in contact with air, with the evolution of ammonia.

How is the bicarbonate of ammonium produced?

NH_4HCO_3, acid ammonium carbonate or bicarbonate of ammonium, is found in deposits of guano on the west coast of Patagonia. Occurring as large triclinic crystals, it volatilizes slowly when exposed to the air, and is soluble in 8 parts of water.

Caustic potash, KHO, a solution of mercuric iodide, HgI_2, and of potassium iodide, KI, together, give to any ammoniacal solution a brown coloration or precipitate of di-mercur-ammonium iodide, NHg_2I :—

$$NH_3 + 2HgI_2 + 4KI + 3KHO = 2H_2O + 7KI + NHg_2I + H_2O.$$

What is the mode of preparing ammonium hydrogen sulphide?

Ammonium hydrogen sulphide, NH_4HS, is prepared by saturating a solution of ammonia with sulphuretted hydrogen gas. It is a yellow liquid with an offensive odor.

What use is this sulphide?

It has great practical utility in chemical analysis, as it yields with most metallic solutions precipitates which are often characteristic.

Give the tests for ammonium compounds.

(1) All the salts are white and volatilized by heat. If heated with caustic potash, soda, or lime they yield ammonia gas, known by its pungent odor and its alkaline reaction on litmus paper.

(2) Perchloride of platinum gives a yellow precipitate of ammonio-platino chloride, NH_4PtCl_5.

(3) Nitrate of silver and a solution of arsenious acid with ammonium hydrate, NH_4HO, give a yellow precipitate.

II. METALS OF THE ALKALINE EARTHS.

What are the characteristics of metals of the alkaline earths?

The metals of the alkaline earths, *calcium*, *strontium*, and *barium*, form oxides less soluble in water than the true alkalies. They exhibit a similar taste, causticity, and action on vegetable colors; their carbonates are insoluble in water; the sulphates of calcium and strontium are slightly soluble; the sulphate of barium is insoluble.

CALCIUM (*calx lime*). Symbol **Ca.** Atomic weight 39.9.

Where does calcium occur?

It is an abundant and widely diffused element, occurring as a carbonate in limestone, marble, chalk, coral, marl, etc. Its sulphate is gypsum; its fluoride, fluorite; its phosphate, apatite, and its silicates are many minerals.

The phosphate is an important ingredient of plants and bones.

Give the mode of preparing calcium and its properties.

(1) Electrolytically from calcium chloride;
(2) By heating calcium iodide with metallic sodium.

It is light yellow in color, hard as gold, very ductile and malleable. It tarnishes slowly in air, decomposes water, burns with a bright light when heated in air, brilliantly when heated in oxygen or vapor of bromine, iodine, or sulphur, and has a specific gravity of 1.5778.

How is calcium chloride prepared?

Calcium chloride, $CaCl_2$, is prepared by the action of hydrochloric acid on calcium carbonate:—

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

What are its properties and uses?

Its colorless, prismatic, strongly deliquescent crystals contain six molecules of water of crystallization, $CaCl_2,6H_2O$. When the water is driven off by heat the anhydrous chloride is in a porous state and absorbs water with great avidity. It is of great use in desiccating gases.

When $CaCl_2,6H_2O$ is mixed with powdered ice or snow it produces a powerful freezing mixture. A temperature as low as —48.5° has thus been obtained.

What are the bromide, iodide, and fluoride of calcium?

$CaBr_2$, calcium bromide, and CaI_2, calcium iodide, closely resemble the chloride.

CaF_2, calcium fluoride, fluorspar, occurs in the mineral fluorite, beautifully crystallized and often highly colored. Some varieties phosphoresce when heated. It is the most abundant source of hydrofluoric acid and is of great value in etching glass.

How is calcium monoxide prepared?

CaO, calcium monoxide, lime, quicklime, is prepared by heating the carbonate:—

$$CaCO_3 = CaO + CO_2.$$

It is produced in great quantities in lime-kilns.

What are the properties of lime?

It is white, caustic, infusible, giving an intense white light in the oxyhydrogen flame (Drummond or calcium light).

It is phosphorescent at a high temperature and unites violently with water, evolving great heat, sufficient sometimes to ignite buildings. Its union with water yields the hydroxide:—

$$CaH_2O_2 \text{ or } CaO,H_2O.$$

How is calcium dioxide prepared?

CaO_2, calcium dioxide, is prepared by the action of hydrogen dioxide on lime-water, thus producing microscopic crystals:—

$$CaO_2,8H_2O.$$

Mention the properties and uses of calcium hydrate.

CaH_2O_2 or $Ca(OH)_2$, calcium hydroxide, caustic lime, or slaked lime, is prepared by the action of water on calcium monoxide.

Alkaline in reaction, it neutralizes acids, attacks organic matter vigorously, and is soluble in 730 parts of cold but 1300 parts of warm water, forming *lime-water*.

Of what use is calcium hydrate?

Its use is very extensive in the preparation of mortars* and cements; in tanneries to remove hair from skins; as a fertilizer, as it decomposes organic matter in the soil and reacts on silicates of potassium, liberating potash for the use of plants; as a purifier for illuminating-gas; in the manufacture of bleaching-powder and caustic alkalies; as milk of lime, suspended in water, for whitewash; as lime-water to test for carbon dioxide.

What is hydraulic cement?

Hydraulic cement is prepared by heating lime containing clay and silica. Moisture converts them into silicates of lime and aluminium, which *set* and become impervious to water.

How is chloride of lime prepared, and what are its properties and uses?

$CaOCl_2$, chloride of lime (bleaching-powder), is prepared by passing chlorine gas over moist calcium hydroxide.

When fresh it is a soft, white powder absorbing moisture from the air. It has a peculiar odor, is soluble in 10 parts of water, is decomposed by the action of carbonic acid in the air, and is the best commercial bleaching-powder. It contains about 30 per cent. of available chlorine. It is used extensively in dilute solutions as a *bleaching-agent*, the chlorine being set free by dilute acids:—

$$CaOCl_2 + H_2SO_4 = CaSO_4 + HClO + HCl;$$
$$HClO + HCl = H_2O + Cl_2.$$

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* Mortar is made by mixing lime with water and sand; for interior plastering hair is added to bind the mass together. When first mixed, mortar is soft and pasty. It hardens as it dries, and by the absorption of carbon dioxide from the air becomes in time almost as hard as stone. In very old brickwork the mortar is often harder than the bricks themselves, due to the formation of the silicate of calcium.

It is also used as a disinfectant. By exposing the chloride in shallow vessels, chlorine is slowly disengaged and mixed with the atmosphere, which it purifies by attacking the hydrogen of the offensive compounds, thus reorganizing their constituents into harmless products.

Give the mode of preparing calcium sulphate.

Calcium sulphate, $CaSO_4$, occurs native in the anhydrous form and as gypsum (selenite) with two molecules of water, $CaSO_4,2H_2O$. It is often associated with rock-salt. It is prepared by the action of sulphuric acid on calcium carbonate:—

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2.$$

What are its properties?

It is soluble in about 500 parts of water, and often occurs with the carbonate in natural waters. Such waters are known as "hard" waters and are objectionable for use in steam-boilers, as the lime salts form a crust known as "boiler scale," which, being a non-conductor of heat, causes great waste of fuel. Hard waters are also objectionable for laundry purposes, the lime salts combining with the soaps to form insoluble lime soaps, and no lather can be produced until all the lime salts have been precipitated. This hardness is termed "*permanent hardness*," as boiling will not remove it.

Of what use is calcium sulphate?

The mineral gypsum when in white, translucent masses (alabaster) is used as an *ornamental stone.*

If gypsum is calcined, the anhydrous sulphate is produced, forming "*Plaster-of-Paris*," which, when mixed with water, reabsorbs the two molecules of water and "sets" to a compact, solid mass. In solidifying it expands and thus is of great value in making casts. It is used to some extent in *fertilizers*, as a "filler," and largely for hard finish to the surface of plastered walls.

State the preparation of calcium nitrate.

$Ca(NO_3)_2$, calcium nitrate, is prepared by the action of nitric acid on chalk. When heated and exposed to sunshine it appears luminous in the dark, and is called "*Baldwin's phosphorus.*"

This nitrate is often found as an efflorescence on walls of stables through which urine and other organic substances have percolated.

Where does the mono-calcic-orthophosphate occur?

Mono-calcic-orthophosphate, $CaHPO_4$, occurs in urinary concretions as stellate groups of microscopic crystals.

State the occurrence, mode of preparation, and properties of tri-calcic-orthophosphate.

The tri-calcic-orthophosphate, $Ca_3(PO_4)_2$, occurs in a few minerals and is the chief mineral constituent of bones. It is prepared by the action of di-sodic orthophosphate, Na_2HPO_4, on an ammoniacal solution of calcium chloride, or from bone-ash and hydrochloric acid. It is a white powder, nearly insoluble in water.

How is the tetra-hydrocalcic-phosphate, $CaH_4(PO_4)_2$, prepared?

Evaporation of either of the preceding phosphates with the requisite quantity of free phosphoric acid forms $CaH_4(PO_4)_2$.

What is superphosphate of lime?

Superphosphate of lime is a name applied to a mixture of mono-calcic-orthophosphate, $CaHPO_4$, and calcium sulphate. It is prepared on a large scale by treating bone-ash, or phosphate minerals, with two-thirds their weight of sulphuric acid, and is used to a very great extent as a fertilizer.

What is hypophosphite of calcium?

Hypophosphite of calcium, $Ca(PO_2H_2)_2$, is prepared from phosphorus and milk of lime. It occurs as four-sided prisms, insoluble in alcohol, and is used *medicinally.*

Where does calcium carbonate occur?

$CaCO_3$, calcium carbonate (chalk, limestone, marble, etc.), occurs in almost every part of the world and is more or less contaminated with iron oxide, clay, and organic matter. In a pure state it forms beautiful transparent crystals. One variety, known as Iceland spar, possesses double refractive power, and is much used in instruments applied to studying polarized light (Nicol's prisms).

How is calcium carbonate prepared?

It is prepared by the addition of an alkaline carbonate to any solution of calcium.

What are its properties?

It is almost insoluble in pure water, but freely soluble in water containing carbonic acid. The hardness of water due to the presence of $CaCO_3$ is called "*temporary hardness*," as this lime salt can be removed:

(1) Partially by boiling, producing precipitations, the CO_2 in water being driven off;

(2) By the addition of lime-water the CO_2 is taken up and the carbonates are thus precipitated;

(3) By addition of ammonium chloride:—

$$2NH_4Cl + CaCO_3 = CaCl_2 + (NH_4)_2CO_3.$$

The solubility of $CaCO_3$ in water containing CO_2, and its subsequent precipitation when the CO_2 is driven off, is the cause of the beautiful stalactites and stalagmites in the great limestone caverns as in the Mammoth Cave, Ky.

Crystallized calcium carbonate is dimorphous, crystallizing in the hexagonal system as the mineral calcite, and in the orthorhombic system as the mineral aragonite. From any of the numerous crystals of calcite the cleavage-form, consisting of a rhombohedron of 105° 5′, can be obtained. The specific gravity of $CaCO_3$, as calcite, is 2.5–2.8; as aragonite, is 2.9–3.28.

Prepared chalk is washed chalk wrought into lumps and dried.

Whiting is the same material, powdered.

THE SULPHIDES OF CALCIUM are:—

Monosulphide, CaS; Bisulphide, CaS_2;
Pentasulphide, CaS_5.

How is calcium phosphide prepared?

Calcium phosphide results when vapor of phosphorus and fragments of lime are heated to redness in a porcelain crucible. It is a chocolate-brown compound, which, when thrown on water, spontaneously produces inflammable hydrogen phosphide.

Mention the tests for calcium.

(1) The spectrum yields a number of bright lines, of which a green line and an orange line on each side of the sodium line are the most characteristic.

(2) The chloride imparts a red coloration to the blowpipe flame.

(3) Ammonium oxalate yields a precipitate of oxalate of calcium; by this test $\frac{1}{500000}$ grain of calcium can be detected.

(4) Silico-fluoric acid yields precipitate.

STRONTIUM.

Symbol **Sr**. Atomic weight 87.2.

Where does strontium occur?

As a carbonate in the mineral strontianite; as a sulphate in celestite; as a chloride or sulphate in many brine springs, mineral waters, sea-water, etc., and in the ash of the plant *Fucus vesiculosus*.

How is it prepared—what are its properties?

By the electrolysis of the fused anhydrous chloride. It is a yellow, malleable metal harder than calcium, melting at a red heat and oxidizing quickly in the air. It burns when heated and decomposes water at common temperatures.

How is strontium chloride obtained?

Strontium chloride, $SrCl_2$, is prepared by the action of hydrochloric acid on strontium carbonate. The chief use of the salts is to produce the red fire of pyrotechnics. For this purpose strontium nitrate, $Sr(NO_3)_2$, is the most serviceable, as it furnishes oxygen.

Red fire mixture	Strontium nitrate	63	per cent.
	Sulphur	18	"
	Potassium chlorate	16	"
	Lampblack	3	"

Give the tests for strontium.

(1) The strontium salts tinge the flame carmine-red.
(2) The spectrum presents five or six lines of red.
(3) It gives no precipitate with silico-fluoric acid.
(4) Sulphuric acid gives an insoluble precipitate.

BARIUM. Symbol Ba. Atomic weight 136.8.

Where does barium occur?

It occurs mainly as the sulphate, the mineral *barite*, and as the carbonate, *witherite.*

What are its properties?

It is prepared by electrolysis from the fused chloride, and is a pale yellow mass, easily tarnishing, and malleable. It gradually oxidizes in the air and decomposes water.

What are the characteristics and use of barium chloride?

Barium chloride, $BaCl_2$, is the residue from the evaporated solution of the natural carbonate in hydrochloric acid :—

$$BaCO_3 + 2HCl = BaCl_2 + H_2O + CO_2.$$

Its crystals are transparent, colorless, and four-sided, soluble in water. The solution is used as a test for sulphuric acid or sulphates, and precipitates a heavy white powder of barium sulphate :—

$$H_2SO_4 + BaCl_2 = BaSO_4 + 2HCl;$$
$$Na_2SO_4 + BaCl_2 = BaSO_4 + 2NaCl.$$

What is barium hydrate?

The hydroxide, $Ba(OH)_2,8H_2O$, is soluble in 20 parts of cold water or 2 parts of hot water. The solution is highly alkaline to test-paper and a valuable reagent, as it is instantly rendered turbid by the smallest traces of carbonic acid.

How is barium nitrate produced?

It is produced by the action of nitric acid on barium carbonate. It occurs as transparent, colorless, anhydrous crystals soluble in eight parts of cold or three parts of hot water.

It is used in the manufacture of *green fire*, the composition of which is:

Barium nitrate		60	per cent.
Sulphur	about	21	"
Potassium chlorate		15	"
Lampblack		4	"

How does barium sulphate occur?

Barium sulphate, $BaSo_4$, occurs as a heavy spar or barite, often beautifully crystallized. Sulphuric acid and any soluble barium salt produce it as a fine white powder. It is one of the most insoluble salts known. The precipitated salt is used as a substitute for white lead in the manufacture of oil paints known as "*blanc fixe.*" It is used to glaze the surface of cards.

Give the tests for barium.

(1) The salts tinge the blowpipe flame green.

(2) The spectrum shows a series of bright lines in the green and fainter bands in the red.

(3) Silicofluoric acid gives a white precipitate.

The soluble salts of barium are poisonous.

III. METALS OF THE MAGNESIUM GROUP.

Mention the members of the magnesium group.

Beryllium, Zinc,
Magnesium, Cadmium.

Give their characteristics.

These metals are all dyads, and burn brightly when heated in the air. They decompose water at high temperatures. They dissolve readily at ordinary temperatures in hydrochloric and dilute sulphuric acids with the evolution of hydrogen. Each forms only one oxide and one sulphide. The oxides, excepting that of magnesium, which is slightly soluble, are insoluble in water.

The sulphates are soluble in water; the normal carbonates and phosphates are insoluble.

BERYLLIUM or GLUCINUM. Atomic weight 9.

Symbol **Be.**

Where does this element occur?

This rare element occurs as a *silicate*, either alone, as in phenacite, with other silicates, as in beryl and a few other minerals, and as *aluminate* in chrysoberyl.

How is it prepared?

It is produced by the action of metallic sodium on the vapor of the chloride of beryllium.

State its characteristics.

It is a white metal, specific gravity 2.1, which may be forged and rolled. Its melting-point is below that of silver; it does not decompose water at a boiling heat; it is soluble in sulphuric and hydrochloric acids with the evolution of hydrogen. The compounds are not medicinally important. The mineral beryl is valuable as a gem. When green it is known as an *emerald*, while the bluish-green is termed *aqua marine.*

MAGNESIUM (Magnesia, a town in Asia Minor).
Symbol **Mg**. Atomic weight 23.94.

Where does magnesium occur?

In many silicates, as talc, serpentine, etc.; as a *carbonate*, *magnesite;* as a *double carbonate of calcium and magnesium*, dolomite, often forming entire mountain ranges; as an *aluminate*, in spinel; as *soluble salts*, in mineral and sea-waters; as a *carbonate* and *phosphate*, in the bodies of plants and animals.

How is it prepared?

(1) Electrolysis of fused magnesium chloride;
(2) By reducing magnesium chloride with metallic sodium.

What are its characteristics?

It is a bluish-white metal, specific gravity 1.75, melting at a red heat, and volatilizing at high temperatures. It is brittle at ordinary temperatures, malleable at a heat little below redness. It tarnishes in moist air, is easily combustible, and burns with a dazzling white light, emitting dense white clouds of solid oxide, MgO. It produces a continuous spectrum containing a large proportion of the more refrangible rays, hence well adapted for photography.

Give the preparation of magnesium chloride.

Magnesium chloride, $MgCl_2$, occurs in sea-water, many brine springs, and in salt beds. It is prepared from hydrochloric acid and carbonate of magnesium in the presence of ammonium carbonate.. It is also produced in large quantities from the salt beds at Stassfurt. It is white, crystalline, deliquescent, and soluble in water and alcohol.

How is magnesium oxide obtained?

MgO, magnesium oxide, magnesia, is prepared by exposure of the hydrocarbonate to a full red heat. It is a soft, white powder, slowly attracting moisture and carbon dioxide from the air. It is soluble in

5000 parts of water at 15.5° C., and is used as a face powder and medicinally.

Where does magnesium sulphate occur?

$MgSO_4,7H_2O$, magnesium sulphate, Epsom salt, occurs in sea-water and mineral springs.

How is it prepared?

It is prepared in large quantities by the action of sulphuric acid on dolomite or magnesite. In the former case it is separated from the almost insoluble calcium sulphate by filtration.

Enumerate its properties.

Its crystals, soluble in an equal weight of water, have a nauseous, bitter taste, and possess purgative qualities. It forms double salts with potassium and ammonium.

Where does magnesium phosphate occur?

$MgHPO_4,7H_2O$, magnesium phosphate, occurs in grains of cereals, and in beer. Its colorless, prismatic crystals are soluble in 1000 parts of water.

Where does the double phosphate of magnesium and ammonium occur?

$Mg(NH_4)PO_4,6H_2O$, the double phosphate of magnesium and ammonium, sometimes forms urinary calculi, and may be converted by heat into the pyrophosphite of magnesium, $Mg_2P_2O_7$.

Mention some of the magnesium silicates and their places in industries.

The silicate minerals are :—

Chrysolite, $2(MgFe),O,SiO_2$, used for ornamental purposes;

Sepiolite (*meerschaum*), $2MgO,3SiO_2$, used for pipe-bowls and cigar-holders;

Talc, $4MgSiO_3,SiO_2,4H_2O$, used for fire-stones and as a powder for diminishing friction;

Serpentine, a combination of silicate and hydroxide: a "fibrous" variety (chrysotile) is used for the manufacture of fire-proof fabrics, ropes, etc.;

Jade, *augite*, and *hornblende* are other common minerals containing magnesium as a silicate.

Give some facts regarding magnesium carbonate.

$MgCO_3$, normal carbonate of magnesium, occurs as mineral magnesite, principally at the island of Eubœa. On account of its infusibility it is used as a refractory material. Magnesia alba is a compound of carbonate and hydroxide.

Give the tests for magnesia.

(1) With any phosphate in the presence of ammonia it yields a white precipitate of ammonium magnesium phosphate, soluble in acids.

(2) The salts are white, acquiring a pink tint when moistened with cobaltic nitrate and heated before the blowpipe.

ZINC. Symbol Zn. Atomic weight 64.9.

What are the sources of zinc?

It occurs in many minerals.

Its chief ores are the oxide, *zincite* and *franklinite* the sulphide, *sphalerite;* and the carbonate, *smithsonite.*

How is zinc prepared?

The ores are first roasted and then heated in earthenware tubes or fire-clay crucibles with coke or charcoal. Metallic zinc is set free and caught in suitable vessels, remelted, and cast into bars known as "*spelter.*"

Enumerate the properties of zinc.

Zinc is a bluish-white metal, tarnishes slowly in air, has a lamellar, crystalline fracture, its specific gravity 6.8 to 7.8. It is brittle under ordinary circumstances and malleable between 120° and 150° C., at which temperature it may be rolled or hammered, after which treatment it retains its malleability when cold. The sheet-zinc of commerce is thus made. At 205° C. it becomes brittle again and may be pulverized. This powder when heated, if air be present, ignites and burns with a luminous green flame. It melts at 423° and boils at 1035°. Dilute acids dissolve zinc readily, liberating hydrogen.

State the uses of zinc.

(1) As a protecting cover for iron, known as "*galvanized iron:*" iron articles, such as plates, rods, wire, etc., are cleansed in dilute sulphuric acid (called "pickling"), then dipped into molten zinc, and thus become coated;

(2) As sheet-zinc for fire-screens, roofing, etc.;

(3) As granulated zinc for generating hydrogen (prepared by pouring a molten stream of zinc into cold water);

(4) As an ingredient of important alloys: *brass* is an alloy of zinc and copper; *German silver*, an alloy of zinc, nickel, and copper;

(5) In batteries.

Give the method of preparation and properties of zinc chloride.

$ZnCl_2$, zinc chloride, is prepared by dissolving zinc in hydrochloric acid and evaporating to dryness. The residue, a white, translucent, pasty solid, is very deliquescent and soluble in water and alcohol.

What application has zinc chloride?

It is used in surgery as a caustic; in embalming bodies; in tinning and soft-soldering copper and iron; as an antiseptic; and in the preservation of wood from decay, called "*Barnettizing.*" The process consists in enclosing wood in strong iron cylinders, exhausting the air, and saturating the wood with $ZnCl_2$ under strong pressure. Copper sulphate, mercuric chloride, coal-tar, creasote, etc., are also employed in the same way as a preservative.

Where is zinc oxide found?

Zinc oxide, ZnO, is found as mineral zincite at Franklin, N. J. The red color is due to the presence of manganese.

How is zinc oxide prepared?

(1) By burning zinc;
(2) By heating the carbonate:—

$$ZnCO_3 + \text{heat} = ZnO + CO_2.$$

What are its properties and use?

It is a white, tasteless powder, yellow when heated, insoluble in water, soluble in acids, and used as a pigment, called "*zinc white.*"

How is zinc sulphate obtained?

$ZnSO_4$, zinc sulphate (white vitriol), occurs as the mineral goslarite. It may be obtained:—

(1) By the action of sulphuric acid on zinc;
(2) By roasting sphalerite (*blende*):—

$$ZnS + O_4 = ZnSO_4.$$

State the properties of zinc sulphate.

It has an astringent, metallic taste; it crystallizes as $ZnSO_4,7H_2O$; is soluble in two and a half parts of cold water; and forms double salts with potassium and ammonium. It is used *medicinally as an emetic.*

How is zinc carbonate obtained?

$ZnCO_3$, zinc carbonate, occurs as the mineral smithsonite. The white precipitate formed by adding a solution of alkaline carbonate to a soluble zinc salt is a mixture of the carbonate and hydrate. When heated to redness it forms a pure zinc oxide.

How is zinc sulphide obtained?

ZnS, zinc sulphide, occurs as the mineral *sphalerite*, also called *blende* and *black jack.*

A hydrated sulphide, ZnS,H_2O, is formed on adding a solution of alkaline sulphide to a soluble zinc salt.

Give the tests for zinc compounds.

(1) *Sulphuretted hydrogen*, H_2S, gives a white precipitate in neutral solutions, but not in acid solutions;

(2) Ferrocyanide of potassium gives a white precipitate;

(3) On charcoal, with sodium carbonate, before the blowpipe, they give a yellow coat of ZnO, which whitens on cooling. If this coat be moistened with cobaltic nitrate and strongly heated, a fine green color is produced.

CADMIUM. Symbol **Cd.** Atomic weight 112.3.

How does cadmium occur?

This comparatively rare metal accompanying ores of zinc also occurs as the mineral greenockite, which is the sulphide.

What are the properties of cadmium?

It closely resembles zinc, is more volatile, and distils over first in the preparation of that metal. It is bluish-white and malleable; specific gravity 8.7. It tarnishes but little in air; burns when strongly heated; melts at 320°, boils at 860°, forming a vapor having only half the density indicated by its atomic weight. Hence its molecule consists of a single atom. Its compounds are analogous to those of zinc.

Are the compounds of cadmium much used?

Excepting the sulphide, CdS, which is used as a pigment, and the iodide, CdI, employed in photography, the cadmium compounds are but little used.

IV. METALS OF THE LEAD GROUP.

Give the characteristics of lead and thallium.

These metals are soft, heavy, and form basic oxides having an alkaline reaction. Thallium in many of its properties closely resembles the alkali metals; and lead resembles the metals of the alkaline earths in forming an insoluble carbonate and sulphate; but lead and thallium are distinguished from both these groups by the black color and insolubility of their sulphides, and from the sparing solubility of their bichlorides.

LEAD (PLUMBUM). Symbol **Pb.** Atomic weight 206.4.

How does lead occur?

It occurs in many minerals, principally as galenite, galena or lead sulphide, and cerussite or lead carbonate.

Give its mode of preparation.

There are four methods for the metallurgical production of lead from its ores :—

(1) *Roasting and reaction*, foreign practice. The sulphide is roasted in a reverberatory furnace to form a sulphate and oxide, and the reaction of these salts on each other produces metallic lead :—

$$2PbO + PbS = SO_2 + 3Pb \text{ and } PbSO_4 + PbS = 2SO_2 + 2Pb.$$

The presence of more than 4 per cent. of SiO_2 debars this method.

(2) *Roasting and reduction*, the type of the U. S. practice. The sulphide is roasted in a reverberatory furnace to form the oxide and then combined with silica to form the silicate. The reduction of metallic lead from this silicate is accomplished in a shaft-furnace by reduced iron ore.

(3) The method of roasting and precipitation is the reduction of the sulphide by means of metallic iron :—

$$PbS + Fe = Pb + FeS.$$

This process is of limited applicability, mainly foreign.

(4) The *mixed method* is based on a combination of the foregoing reactions. Its limited applicability is also mainly foreign.

The lead produced by these methods often contains antimony and other metals which render it *hard*. These impurities may be removed by oxidation in a reverberatory furnace, producing *soft* lead. Should the purified lead contain silver in sufficient quantity to render it worth extracting, it is separated as described under Silver.

A great part of the silver produced in the world is obtained from argentiferous galena.

What are the properties of lead?

It is a bluish-white, soft, malleable metal. It may be drawn out into coarse wire or hammered into plate, but has little elasticity or tenacity. It melts at 334° and boils and volatilizes at higher temperatures. When freshly cut the brilliant metallic lustre quickly tarnishes in moist air, particularly if carbonic acid be present. It rapidly absorbs oxygen when molten. By slow cooling it may be crystallized in octahedral crystals. Dilute acids, excepting nitric, act but slowly upon lead.

The salts of lead are all poisonous, even the slightest traces taken into the system daily will in time accumulate and cause serious illness, hence it is very important to prevent the presence of these salts in drinking-water. Pure water free from air does not attack lead. When air is present the oxide of lead is formed, and this dissolving in the water exposes successive portions of the metal to oxidation.

Waters containing *nitrates*, *chlorides*, *sulphates*, or much *carbonic acid* gradually take lead into solution. Hard waters, or waters containing either *sulphates* or *carbonates*, soon form a thin insoluble coating on the surface of lead pipe, thus protecting it from further oxidation. Such waters therefore are relatively safe.

What are the chlorides of lead?

Lead dichloride, $PbCl_2$, is prepared from common salt or hydrochloric acid mixed with lead nitrate or acetate. It is a heavy white precipitate soluble in 33 parts of boiling water, from which solution it crystallizes by cooling into needle-shaped crystals.

Lead perchloride, $PbCl_4$ (probably), is formed from a solution of lead dioxide and strong hydrochloric acid.

State the uses of lead.

Used as sheet lead in sulphuric acid chambers; as lead pipe, sometimes tin-lined; as plumbers' solder, which is an alloy of 2 parts lead and 1 part tin, and in the manufacture of shot; also in type-metal, which contains a little antimony to give sharp edges to the cast.

State the oxychlorides of lead.

The oxychlorides are :—

$Pb_3Cl_2O_2$,	the mineral mendipite;
Pb_2Cl_2O,	Pattison's white oxychloride;
$PbCl_2,7H_2O$,	patent yellow or Turner's yellow.

The two latter oxychlorides are used as pigments.

State the preparation and properties of lead iodide.

Lead iodide is prepared from potassium iodide and lead nitrate; it is a bright yellow powder, soluble in boiling water, and crystallizes in beautiful yellow iridescent spangles.

Give the oxides of lead and their mode of preparation.

Diplumbic oxide or *suboxide*, Pb_2O, is prepared by heating the monoxide in a retort. It is a gray, pulverulent substance, rapidly absorbing oxygen.

Lead *monoxide*, *litharge*, *massicot*, PbO, may be obtained :—

(1) By direct oxidation of metallic lead;

(2) By heating the carbonate to a dull redness.

It is a delicate straw-colored powder, slightly soluble in water, and yielding an alkaline solution. It melts at a red heat, and tends to crystallize on cooling.

In the melted state it attacks and dissolves siliceous matter with great avidity, often penetrating an earthen crucible in a few minutes. It is readily reduced by heating with organic substances and forms a large class of salts, called *plumbic salts*. It is used medicinally and in the manufacture of glass and glazing earthenware.

The *sesquioxide*, Pb_2O_3, is a reddish-yellow powder.

The *triplumbic tetroxide*, red lead, Pb_3O_4, the composition of which is not constant, is obtained by exposing the monoxide for a long time at a red heat to the action of air. It is a brilliant red powder, decomposing at a red heat with the evolution of oxygen. As a pigment it is a cheap substitute for vermilion. It is used in the manufacture of flint glass and in the preparation of some cements.

Lead *dioxide*, brown dioxide, PbO_2, is the residue from digesting red lead in nitric acid.

Its great affinity for sulphurous oxide, SO_2, renders it useful as an absorbent for this gas :—

$$PbO + SO_2 = PbSO_4.$$

What is the origin of lead sulphate?

$PbSO_4$, lead sulphate, occurs native as the mineral anglesite. In the laboratory it may be prepared by the action of sulphuric acid on any soluble lead salt, and is then precipitated as a white powder soluble in alkalies.

The formulæ for lead nitrate, lead phosphate, and lead acetate are :—

$Pb(NO_3)_2$, $Pb_3(PO_4)_2$, $Pb(C_2H_3O_2)_2$, respectively.

How is lead carbonate obtained?

Normal lead carbonate, $PbCO_3$, occurs as the mineral cerussite, but it may be artificially produced :—

(1) By a cold solution of lead acetate and ammonium carbonate ;
(2) By passing carbon dioxide through a dilute solution of lead acetate.

What are the basic carbonates of lead?

Lead forms several basic carbonates, the most important of which is *white lead*, $2PbCO_3,3H_2O$. It is manufactured on a large scale for pigment. There are several processes of preparation, the more important being :—

(1) *The old Dutch method.*—Jars containing sheet-lead are for a long time exposed to the action of carbon dioxide, which is produced by the fermentation of spent tan-bark or saw-dust mixed with a little vinegar.

The chemistry of this process is as follows: The heat generated from the fermentation causes the acetic acid of the vinegar to be given off as vapor, which attacks the lead, forming a basic acetate. The action of CO_2 from the fermentation converts this acetate into a carbonate.

(2) By dissolving lead oxide in a normal acetate solution, forming a basic acetate, from which lead carbonate is precipitated by passing carbon dioxide through the solution.

What are its properties and use?

It is a heavy, white, amorphous powder—showing, under the microscope, round, transparent globules, measuring from one to four hundred thousandths of an inch in diameter. It is used as a pigment, often adulterated with barium sulphate and zinc oxide.

Although white lead is by far the most brilliant of the white paints, its use is somewhat objectionable as it is readily blackened by sulphuretted hydrogen, and is poisonous to painters who handle it.

How does lead sulphide occur?

PbS, lead sulphide or galena, as the mineral galenite, the most important ore of lead, in crystals of the isometric system, generally cubes, of a bluish-gray color; as *artificial crystals* by passing sulphur vapor over metallic lead; or as a *black amorphous precipitate* by passing sulphuretted hydrogen through a solution of lead salt in the presence of hydrochloric acid.

Give the tests for lead salts.

(1) *Caustic potash* or *soda* yields a white precipitate, freely soluble in an excess of caustic;

(2) *Ammonia* gives a similar white precipitate, not soluble in excess;

(3) *Carbonates of potassium, sodium*, and *ammonium* precipitate lead carbonate, insoluble in an excess;

(4) *Sulphuric acid* or *sulphate* gives a white precipitate, insoluble in an excess;

(5) *Hydrogen sulphide* and *ammonium sulphide* yield an amorphous black precipitate of sulphide;

(6) *Charcoal* and *sodium carbonate* before the blowpipe yield the malleable metal.

THALLIUM. Symbol **Tl.** Atomic weight 203.6.

Where does the very rare metal thallium occur?

Thallium is found in specimens of iron and copper pyrites, in zincblende in *lepidolite*, and in the Neuheim salt-works. It is usually obtained from the tubes or burners in sulphuric acid works. It is a heavy metal resembling lead, soft and malleable. It furnishes the spectrum with a single green line. It is univalent in the thallous, and trivalent in the thallic compounds. It forms two oxides, Tl_2O and Tl_2O_3, with corresponding chlorides, iodides, bromides, and oxygen salts. Most of its salts are poisonous.

Thallium is named from *thallos*, green, from the green lines seen in its spectrum. It was discovered by Crookes in 1861.

V. METALS OF THE COPPER GROUP.

Give the peculiarities of the copper group—copper, mercury, and silver.

Each of these metals forms several oxides and two series of salts, the constitution of which is best represented, as will be presently explained, by regarding the metals as dyads, although copper and silver figure in Mendelejeff's series as monads. These metals do not decompose water at a red heat; they are precipitated from their solutions in the metallic state by zinc, iron, and the more oxidizable metals. Their lower chlorides are insoluble in water.

COPPER (CUPRUM). Symbol **Cu.** Atomic weight 63.1.

Where does copper occur?

Widely diffused in the mineral kingdom; its important ores are the *native copper* of Lake Superior; the *sulphide* as chalcocite, or with iron and sulphur as chalcopyrite and bornite; the *oxide* as cuprite; and the *carbonate* as malachite and azurite.

How is copper obtained?

It is industrially prepared :—

(1) From the *native* mineral by purification (termed "*refining*") in the reverberatory furnace.

(2) From the sulphides of iron and copper (its principal source) by a rather complicated process, essentially as follows: The ore is roasted, by which much of the iron sulphide is converted into the oxide. The product is then put through a furnace, the oxide of iron combining with the silica of the ore, forming a fusible slag, while the copper, sulphur, and the remaining iron combine to form a fusible "matte." The slag, being much lighter than the "matte," is easily separated. When nearly all the iron and sulphur have been eliminated by a repetition of this operation the product is "black copper," containing about 5 per cent. of impurities, mainly iron, from which it is freed by a refining operation in a reverberatory furnace.

(3) From the *oxides and carbonates* it is easily reduced in a shaft furnace by carbonaceous material to black copper, which is then submitted to the refining operation of the reverberatory furnace.

(4) Copper has been extracted to a minor extent by lixiviating methods. It can also be prepared by electrolytic deposition from its solutions, or by reduction of its oxide by hydrogen.

Enumerate its properties.

Copper is of a reddish color, specific gravity 8.95, very malleable, ductile, and tenacious; an excellent conductor of heat and electricity; melts at a bright red heat; slightly volatile at high temperatures, imparting a green tinge to flame; unaltered in dry air, but if exposed to moist air it becomes covered with a strong adherent green crust of carbonate; heated to redness in air it becomes coated with a black scale of oxide. It is but slightly acted upon by dilute sulphuric and hydrochloric acids; soluble in hot sulphuric acid, evolving sulphurous oxide fumes, and in nitric acid, evolving fumes of nitrogen dioxide.

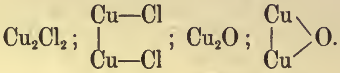
The cupr*ic* compounds are bivalent and stable, consisting of one atom of metal combined with 2 atoms of a univalent or 1 atom of a bivalent negative radical, viz.:—

$$Cu{=}Cl_2\ ;\ Cu{=}O\ ;\ Cu{=}(NO_3)_2\ ;\ Cu{=}SO_4,\ \text{etc.}$$

It also forms another series, the cupr*ous* compounds, in which it may be regarded as univalent, viz.:—

$$Cu{-}Cl\ ;\ Cu_2O\ ;$$

or bivalent, as:—



$$Cu_2Cl_2\ ;\ \begin{array}{l} Cu{-}Cl \\ \mid \\ Cu{-}Cl \end{array}\ ;\ Cu_2O\ ;\ \begin{array}{l} Cu \diagdown \\ \mid \qquad \rangle O. \\ Cu \diagup \end{array}$$

These "*ous*" compounds are very unstable and easily converted into the *ic* compounds.

What are the chlorides of copper?

Cupric chloride, $CuCl_2$, is obtained by the action of copper oxide and hydrochloric acid. It crystallizes in green crystals, $CuCl_2,2H_2O$, and is very soluble in water and alcohol.

Cuprous chloride, Cu_2Cl_2, is prepared:—

(1) By copper in chlorine gas;

(2) By precipitation from solutions of cupric chloride by stannous chloride:—

$$2CuCl_2 + SnCl_2 = Cu_2Cl_2 + SnCl_4.$$

It is a white fusible substance, easily oxidized, and slightly soluble in water.

How is copper monoxide prepared?

Copper monoxide, cupric oxide, CuO, black oxide of copper, is prepared:—

(1) By heating metallic copper with an excess of air;

(2) By decomposing the nitrate by heat.

Cupric salts mixed with caustic alkalies in excess yield bulky pale blue precipitates of hydrated cupric oxide, CuH_2O_2. It is soluble in acids and colors glass green.

How is cuprous oxide prepared?

Cuprous oxide, suboxide of copper or red oxide, occurs as the mineral cuprite, and may be obtained:—

(1) By heating black oxide and copper filings;

(2) By boiling a solution of sulphate of copper, caustic potash, and grape-sugar.

What are its properties?

As a native mineral, when crystallized it has a beautiful blood-red color; is soluble in an excess of hydrochloric acid; is decomposed by most oxyacids, forming cupric salts and metallic copper. It imparts a beautiful red color to glass.

How is copper sulphate obtained?

Sulphate of copper, blue vitriol, is found sparingly as the mineral chalcanthet, and is prepared by treating cupric oxide in sulphuric acid. It forms large blue triclinic prisms of $CuSO_4,5H_2O$, soluble in 4 parts of cold or 2 parts of hot water, which becomes a white powder when anhydrous. It forms double salts with potassium and ammonium, and is used mainly for gravity batteries.

How is copper nitrate produced?

$Cu(NO_3)_2,3H_2O$, cupric nitrate, is formed by treating copper with nitric acid. Its deep blue crystals are soluble, deliquescent, and highly corrosive.

What is copper carbonate?

Cupric carbonate occurs native, as the minerals azurite and malachite. Azurite is deep blue in color, malachite a deep green. It is sometimes used for jewelry and ornaments. The artificial green carbonate is used as a pigment.

Give the sulphides of copper.

Cupric sulphide, CuS, occurs sparingly as the mineral covellite. It is prepared by passing hydrogen sulphide through a solution of a cupric salt.

Cuprous sulphide, Cu_2S, occurs as the mineral chalcocite. It is prepared from metallic copper by heating with vapor of sulphur.

State the ammoniacal compounds of copper.

The chlorides, sulphates, nitrates, and other salts of copper unite with one or more molecules of ammonia, forming crystalline compounds of a green or blue color.

Give the tests for copper compounds.

(1) *Ammonia* precipitates the hydroxide, soluble in an excess, yielding a deep blue solution;

(2) *Potassium and sodium carbonates* give precipitates of cupric carbonate insoluble in an excess;

(3) *Ammonium carbonate* yields the same, but soluble in an excess to a deep blue solution;

(4) *Potassium ferrocyanide* gives a red-brown precipitate of cupric ferrocyanide;

(5) *Hydrogen sulphide and ammonium sulphide* give black cupric sulphide insoluble in ammonium sulphide;

(6) *Metallic iron* or *zinc* immersed in a solution of a copper-salt precipitates metallic copper;

(7) They impart a green color to flame;

(8) With borax they yield, in the oxidizing flame, a green color when hot, blue when cold; in the reducing flame the bead becomes red and opaque;

(9) They can be reduced to metallic copper when mixed with sodium carbonate or potassium cyanide and heated.

Give some of the useful alloys of copper.

Brass, copper with about 30 per cent. zinc;
Gun-metal, copper with about 10 per cent. tin;
Bell and *speculum metals*, copper with larger per cent. of tin;
Bronze, copper with 10 per cent. of zinc, tin, and lead.

Copper is extensively used in electrotyping; in constructing electrical apparatus; as telegraph wires; as a sheathing for ships; as coins, etc. Its green salts, the arsenite and the double salt arsenite and acetate, from the pigments *Scheele's green* and *Paris green*. The latter is extensively used as an insect destroyer, particularly for the Colorado beetle or potato bug.

SILVER (ARGENTUM). Symbol Ag. Atomic weight 107.66.

How does silver occur?

It occurs in a *metallic state* as a *sulphide*, *argentite;* and as a sulphide of arsenic, *proustite*, and with sulphide of antimony, *pyrargyrite;* as *chloride*, *iodide*, *bromide*, and *telluride*, and with other minerals as argentiferous galena.

How is silver prepared?

By a great variety of processes, as:—

(1) By fusion of silver-bearing material with lead ores and subsequent separation;

(2) By fusion with copper ores and subsequent separation;

(3) By amalgamation

(4) By lixiviation.

When with lead the silver is obtained as argentiferous lead, by a regular process described under Lead. The product is called "*base bullion*" or "*work lead.*" The silver is separated therefrom by the process of zinc desilverization, based on the principle that silver has a greater affinity for zinc than for Lead. Metallic zinc is added to the molten lead and is itself melted. By lowering the temperature the zinc solidifies, as its melting-point is higher than that of lead, and forms with some silver and lead a crust or scum on the surface of the lead. Only a small amount of zinc is necessary to extract practically all the silver. The silver is separated from the *zinc* by placing them in a retort with charcoal. The zinc distils over and is condensed, leaving the silver with a very small amount of zinc and a little lead in the retort. This silver is then "cupelled," the lead and zinc being oxidized and driven off, and the silver remaining in the cupel almost absolutely pure.

When with copper the silver is generally obtained from the black copper by electrolysis, or from a solution in acids. From a rich matte it is obtained by roasting the silver sulphide to sulphate and leaching with hot water, from which solution it is precipitated by metallic copper.

When silver does not occur with lead or copper ores, or lead and copper ores are not available, the process of amalgamation is employed. The ore is finely ground and made into a thin paste with water. Mercury is then introduced, which unites with the silver, forming an amalgam, from which the silver is obtained by distillation. The distilled mercury condenses and is used again.

When silver ores do not contain copper or lead enough to smelt, and are too poor to pay for amalgamation, one of the processes of lixiviation, of which there are several, is sometimes used :—

The roasting of the ore with salt forms silver chloride. Then follows its solution in thiosulphate of sodium (called hyposulphite of sodium), from which it is precipitated as a sulphide.

In the reduction of a silver salt by means of metallic zinc the gray and spongy silver obtained may be purified by washing with acidulated water.

What are the properties of silver?

It is white and lustrous ; specific gravity 10.512 ; exceedingly malleable and ductile ; the best conductor of heat and electricity. It melts at 1040° C., and may be vaporized and distilled at very high temperatures. Its vapor has a bright blue color. Molten silver absorbs many times its bulk of oxygen from the air and gives it out again when cooling, sometimes so suddenly as to cause explosive sputterings called "spitting." This absorption of oxygen is prevented by the presence of 2 per cent. of copper. Silver is but slightly attacked by hydrochloric acid, but is soluble in hot sulphuric acid and readily soluble in nitric acid, even dilute. It is unaltered by air or moisture. The tarnishing of silver is due to the formation of a sulphide film from the presence of sulphuretted hydrogen in the air.

How does argentic chloride occur?

$AgCl$ or Ag_2Cl_2, argentic chloride, occurs as a mineral : *Cerargyrite, horn silver ;* and with *bromine* and *iodine*, *bromargyrite*, *embolite*, and *iodyrite.*

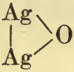
State the method of preparing argentic chloride and its properties.

It is the result of union between any chloride and a silver salt. It is a white curdy precipitate ; insoluble in water and nitric acid, soluble in 200 parts of concentrated HCl. It melts when heated, forming a gray crystalline mass which cuts like horn and is decomposed by light. It is reduced by metallic zinc or iron and is easily soluble in ammonia, in a solution of common salt, or potassium cyanide.

How is argentous chloride prepared?

Argentous chloride, Ag_4Cl_2, is formed by the action of hydrochloric acid on argentous oxide. Heat or ammonia easily decomposes it into argentic chloride. The sensitiveness of the silver salts of bromine, iodine, and fluorine to light makes them useful in photography.

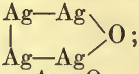
How is argentic oxide prepared?

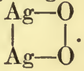
Argentic oxide, Ag_2O,  $\left.\begin{array}{l}Ag\\ |\\ Ag\end{array}\right\rangle O$, is prepared by adding caustic potash to silver nitrate:—

$$2AgNO_3 + KOH = Ag_2O + KNO_3 + HNO_3.$$

It is a strong base, forming salts isomorphous with alkali metals and giving pale brown precipitates. It is soluble in ammonia and to a slight extent in water, yielding an alkaline solution. It neutralizes acids; is decomposed by a red heat with the liberation of oxygen, leaving the silver as a metallic sponge.

What other oxides of silver are known?

Argentous oxide, Ag_4O, or  $\left.\begin{array}{l}Ag—Ag\\ |\\ Ag—Ag\end{array}\right\rangle O$;

Argentous dioxide, Ag_2O_2, or  $\begin{array}{l}Ag—O\\ |\quad\;\; |\\ Ag—O\end{array}$.

What are the oxysalts of silver?

Silver sulphate, Ag_2SO_4; prepared by boiling metallic silver in concentrated sulphuric acid, or by the precipitation of a silver nitrate solution with an alkaline sulphate:—

Silver dithionate, $Ag_2S_2O_6$;
Silver thiosulphate, $Ag_2S_2O_3$.

Silver nitrate, $AgNO_3$, or lunar caustic, is prepared by dissolving metallic silver in nitric acid. It separates from the solution in colorless anhydrous transparent tables, soluble in an equal weight of cold or in one-half its weight of boiling water and also in alcohol. It fuses when heated and blackens when exposed to light in the presence of organic matter. It is used in cautery, indelible inks, hair dye, and as a reagent test for hydrochloric acid.

Silver carbonate, Ag_2CO_3, is prepared by the action of sodium carbonate on silver nitrate. It is a white insoluble substance, blackened and decomposed by boiling.

How is silver sulphide prepared?

Ag_2S, silver sulphide, occurs as the mineral *argentite*. It may be prepared by the action of hydrogen sulphide on a silver solution, or by melting silver and sulphur together. It is a gray, soft, malleable substance, a strong sulphur base, combining with the sulphides of arsenic and antimony.

Give the method of preparing silver cyanide.

Cyanide of silver, $AgCN$, will be formed as a precipitate if potassium cyanide be added to a solution of silver nitrate. It dissolves by the addition of more potassium cyanide. This solution is extensively used in silver-plating.

Give the process of silver-plating.

In a solution of silver cyanide, variously prepared, the object to be plated is immersed with a bar or plate of pure silver. The latter is connected by wire to the negative element of a battery, while the object to be plated is connected with the positive. Electrolysis takes place, dissolving the silver from the bar or plate and depositing a thin coat or film on the object. The process is carried on until the silver is deposited to a desired thickness. After this the plated article is washed and polished. The same general method is employed, but with different solutions, when plating with gold, copper, platinum, or nickel.

What is Berthollet's fulminating silver?

By digesting silver oxide with ammonia a black explosive compound is formed, which, when dry, may be exploded by the merest touch. A similar compound, containing oxide of gold, also exists.

What are the tests for silver compounds?

(1) *Hydrochloric acid* gives a white curdy precipitate, which is soluble in ammonia, darkens by exposure to light, and is insoluble in nitric acid;
(2) *Iron, copper, or mercury* reduces a silver salt to a metallic state;
(3) *Hydrogen sulphide* gives a black precipitate of silver sulphide, insoluble in *ammonium sulphide;*
(4) *Alkaline carbonates* give white precipitates soluble in ammonia;
(5) *Sodium phosphate* gives a yellow precipitate;
(6) *Potassium chromate or bichromate* gives a red-brown precipitate.

Mention the uses of silver.

(1) Its uses are extensive, for table and culinary purposes;
(2) For coinage: The U. S. standard being 9 parts of silver to 1 of copper; jeweller's silver is generally more freely alloyed;
(3) For silver-plating, bric-a-brac, ornaments, etc.

MERCURY (HYDRARGYRUM, *huder* = water, *arguros* = silver).

Symbol **Hg**. Atomic weight 199.8.

How does mercury occur?

Mercury, often called *quicksilver*, occurs mainly as sulphide in the mineral cinnabar; as *metallic globules* disseminated through the *sulphide, cinnabar;* also in unimportant amounts in other ores. It may be prepared in furnaces by reducing the ore with iron or lime, the volatilized mercury being condensed in suitable chambers or pipes, and sent into commerce in wrought-iron bottles holding 75 pounds each.

State the properties of mercury.

It is a silver-white lustrous metal, specific gravity 13.596, liquid at ordinary temperatures, solidifying at —39.5° C., in which state it is soft and malleable. It boils at 357° C., yielding a vapor of density 100, showing that the mercury, like the cadmium, molecule consists of *one atom.* It volatilizes to a considerable extent at all temperatures above 20° C., but is unaltered in air at common temperatures. When heated to near its boiling-point it absorbs oxygen. It is insoluble in HCl or dilute H_2SO_4, but soluble in concentrated H_2SO_4 and HNO_3. It combines directly with chlorine, bromine, iodine, and sulphur.

Give the modes of preparing mercuric chloride.

$HgCl_2$, mercuric chloride (corrosive sublimate), may be prepared:—

(1) By metallic mercury in chlorine gas;

(2) By mercuric oxide in hot hydrochloric acid and crystallized by cooling.

(3) By subliming a mixture of equal parts of mercuric sulphate and common salt:—

$$HgSO_4 + 2NaCl = HgCl_2 + Na_2SO_4.$$

Give its properties.

It is a white transparent crystalline mass, which melts at 265° C., boils at 295° C., and is soluble in 16 parts of cold or 3 parts of boiling water; also soluble in alcohol and ether. It combines with a great number of other metallic chlorides, absorbs ammonia gas with great avidity, forming $HgCl_2.NH_3$. It forms insoluble compounds with many of the azotized organic principles, as albumen, etc. It is probable that to this quality its strong *antiseptic* properties are due. Animal and vegetable substances are preserved by it according to Kym's methods of preserving timber and cordage. In case of poisoning, albumen is an excellent antidote.

How is mercurous chloride produced?

HgCl or Hg_2Cl_2, mercurous chloride (calomel), is prepared:—

(1) By a solution of mercurous nitrate in a dilute solution of common salt;

(2) By subliming an intimate mixture of dry mercuric sulphate, mercury, and salt:—

$$HgSO_4 + Hg + 2NaCl = Hg_2Cl_2 + Na_2SO_4.$$

Give its properties.

It is a heavy, white, insoluble, tasteless powder. It vaporizes below redness, condensing to a yellow-white crystalline mass, soluble in boiling hot nitric acid. It is apt to contain some corrosive sublimate, a dangerous contamination when calomel is used for medicinal purposes. Recent experiments tend to show that the true formula is $HgCl$. It is much used *medicinally.*

How is mercuric iodide obtained?

HgI_2, mercuric iodide, is prepared from a solution of mercuric chloride and potassium iodide. Yellow at first, it then becomes a scarlet dimorphous precipitate. It is employed *medicinally.*

How is mercurous iodide prepared?

Hg_2I_2, mercurous iodide, is formed from mercurous nitrate and potassium iodide. A greenish-yellow precipitate results from their union. *Medicinally* it is useful.

State the methods of preparing the oxides of mercury.

HgO, mercuric oxide; red oxide of mercury; red precipitate:—
(1) Oxidizing mercury at high temperature;
(2) Decomposing the nitrate by heat;
(3) Excess of caustic potash added to a solution of corrosive sublimate.

Properties: Red color; slightly soluble in water, giving alkaline reaction and metallic taste; highly poisonous; decomposed by heat into mercury and oxygen. A yellow or amorphous form is used with oleic acid for skin diseases.

Hg_2O, mercurous oxide, *suboxide or gray oxide of mercury:*—
(1) Caustic potash added to mercurous nitrate;
(2) Digesting calomel with caustic potash. It is a grayish-black heavy powder insoluble in water and slowly decomposed by the action of light.

The preparations known as *blue-pill*, *gray ointment*, *mercury with chalk*, etc., contain merely the finely divided metal.

How are the nitrates of mercury obtained?

Mercury and cold dilute nitric acid yield the mercurous nitrate, while hot concentrated nitric acid and mercury yield the mercuric nitrate.

What are the sulphates of mercury?

Mercuric sulphate, $HgSO_4$, is derived from mercury and hot concentrated sulphuric acid, and used in some forms of galvanic batteries.

Mercurous sulphate, Hg_2SO_4, is prepared from mercurous nitrate and sulphuric acid.

How is mercuric sulphide obtained?

HgS, mercuric sulphide, occurs as the mineral cinnabar, the principal source of mercury. It is also formed:—

(1) By an excess of sulphuretted hydrogen passed through mercuric nitrate or chloride;

(2) By subliming a mixture of 6 parts of mercury and 1 part of sulphur.

State its properties and use.

(1) A black precipitate, changed by sublimation to a dark red and crystalline form.

(2) A red powder called vermilion. Its beauty of tint depends upon its fineness of division. Heated in air it decomposes to metallic mercury and sulphur dioxide. It is insoluble in caustic alkalies and mineral acids, excepting *aqua regia*. Its use is extensive as the pigment vermilion.

How is mercurous sulphide prepared?

Hg_2S, mercurous sulphide, is prepared by passing sulphuretted hydrogen into a mercurous nitrate. The process forms a black precipitate decomposed by heat into mercuric sulphide and mercury.

What are the ammoniacal mercury compounds?

By the action of ammonia and its salts upon salts of mercury, a great variety of substances is formed. They may be regarded as salts of mercur-ammoniums, that is of ammonium molecules in which the hydrogen atoms are more or replaced by mercury according as the compound is formed from a mercurous or mercuric salt.

Give the tests for mercury compounds.

(1) All mercury salts are volatilized or decomposed at the temperature of ignition;

(2) *Copper* precipitates mercury from solutions;

(3) *Stannous chloride* forms a precipitate;

(4) *Hydrogen sulphide* and *ammonium sulphide* produce black precipitates, insoluble in *ammonium sulphide;*

(5) *Potassium iodide* yields a bright scarlet precipitate with mercur*ic* salts, and a green precipitate with mercur*ous* salts;

(6) *Charcoal* and *sodium carbonate* yield metallic mercury.

What are some of the uses of mercury?

(1) Metallic mercury is used in the construction of barometers, thermometers, and other physical apparatus;

(2) To extract gold and silver from their ores by forming their amalgams;

(3) With tin it forms an amalgam for silvering glass-mirrors, and with silver and gold an amalgam for filling teeth.

VI. METALS OF THE YTTRIUM GROUP.

State some of the facts regarding the yttrium group.

This group includes a considerable number of metals occurring in gadolinite, cerite, samarskite, and other rare minerals. The extraction and separation of the oxides of these metals are complex and difficult, and the number of distinct oxides or earths thus obtained is not exactly known. The existence of some of these metals is still a matter of dispute. The ten following may be considered established:—

	Symbol.	Atomic weight.		Symbol.	Atomic weight.
Scandium . . .	Sc	44;	Samarium . .	Sm	150;
Yttrium . . .	Y	89;	Terbium . . .	Tb	149;
Lanthanum . .	La	138;	Decipium . . .	Dp	159;
Cerium . . .	Ce	141.6;	Erbium . . .	Er	169;
Didymium . .	D	145.4;	Ytterbium . .	Yb	173.

These rare metals have only theoretical importance. The existence of scandium was predicted by Mendelejeff in advance of its actual discovery in nature. Cerium oxalate has a limited use in medicine.

VII. METALS OF THE ALUMINIUM GROUP.

What are the members of the aluminium group?

Aluminium, indium, gallium.

Give the characteristics of the aluminium group.

These metals are trivalent, forming compounds of the forms MCl_3, M_2O_3, etc.

Their oxides are weak bases and their sulphates unite with those of the alkali metals, forming double salts called "alums," which crystallize in regular forms of the isometric system.

ALUMINIUM. Symbol **Al.** Atomic weight 27.3.

Where is aluminium found?

Regarding its abundance in nature it may be ranked with sodium, calcium, and magnesium. As a *silicate*, it enters into the composition of all primitive rocks, of feldspars, slates, and clays; of the minerals *garnet*, *emerald*, *topaz*. As an *oxide*, Al_2O_3, it is the mineral corundum, which in its various degrees of coloring and purity is the *ruby*, *sapphire*, *Oriental topaz*, Oriental amethyst, and Oriental emerald. An impure variety is called emery. As a *phosphate*, it occurs as turquoise. As a *fluoride*, it occurs as cryolite, $Al_2F_6,6NaF$. As an *aluminate*, with iron, *bauxite*, a hydrated aluminate of iron. It is also a constituent of other less important minerals.

Give several methods of preparing aluminium.

(1) By decomposing aluminium chloride by metallic potassium (Wöhler's original method).

(2) By decomposing the double chloride of sodium and aluminium, $AlF_3,3NaF$, by metallic sodium (Deville's process).

Both of these original processes have been supplanted by the modern electric methods :—

(3) The electrolytic reduction of oxide of aluminium having a cover of fused cryolite, producing metallic aluminium (Heroult and Hall's processes) ; and

(4) The electrolytic reduction of corundum, Al_2O_3, with copper, producing an alloy of copper and aluminium (Cowle's process).

State the properties and uses of aluminium.

It is a tin-white metal, brilliant and capable of being highly polished ; specific gravity 2.6 to 2.74 ; malleable and ductile ; an excellent conductor of heat and electricity. It does not readily tarnish in air ; is easily worked, and combines the properties of lightness and strength to an extraordinary degree. Its specific heat is very high, 0.2253, being double that of iron. Its melting-point is 625° C. It imparts great strength to its alloys. It is trivalent ; forms only one class of compounds. As a metal it is used in the manufacture of delicate apparatus and ornamental objects. As an alloy with copper, called aluminium bronze, and with steel it is coming into constantly increasing use.

What chemicals will produce aluminium chloride ?

Aluminium chloride, $AlCl_3$, is produced by :—

(1) Aluminium hydrate in hydrochloric acid (in solution) ;

(2) Alumina, finely divided carbon, and chlorine gas :—

$$Al_2O_3 + C_3 + Cl_6 = 2AlCl_3 + 3CO$$

(an anhydrous solid).

What is the aluminium sodium salt ?

$AlCl_3,NaCl$, aluminium and sodium chloride, is a double salt obtained by melting together the proper proportions of the two chlorides.

How is aluminium fluoride prepared ?

AlF_3, aluminium fluoride, is prepared by the action of gaseous silicon fluoride on alumina. Its cubic crystals, volatilizing at a red heat, are insoluble in water and resist the action of acids.

What is the aluminium sodium fluoride?

$AlF_3,3NaF$, aluminium and sodium fluoride, is found in nature as cryolite at Evigtok, Greenland.

How is it prepared and what is its use?

It is prepared from hydrofluoric acid and a mixture of calcined alumina and sodium carbonate. Its natural crystals, softer than feldspar, are used in the preparation of aluminium; for the manufacture of soda-ash; for aluminium sulphate, and in the production of glass resembling porcelain.

How does aluminium oxide occur?

Al_2O_3, aluminium oxide or alumina, occurs as the mineral corundum. It may be prepared from aluminium sulphate and an excess of ammonia hydrate. The bulky, white, gelatinous precipitate of aluminium hydrate thus obtained is converted into an oxide by ignition. The oxide is a white, tasteless, coherent mass, and little affected by acids, but fusible before the oxyhydrogen blowpipe. It acts as a weak base.

Give the hydrates of aluminium.

Monohydrate,	Al_2O_3,H_2O	or $AlO(OH)$;
Dihydrate	$Al_2O_3,2H_2O$	or $Al_2O(OH)_4$;
Trihydrate	$Al_2O_3,3H_2O$	or $Al(OH)_3$.

The monohydrate occurs native as diasphore dihydrate. The trihydrate occurs native as gibbsite. It has a powerful attraction for organic matter and precipitates solutions of vegetable coloring-matters forming pigments called "*lakes.*" The fibre of cotton impregnated with alumina acquires the power of retaining coloring-matters, hence the great use of aluminous salts as *mordants* to produce fast colors.

What are aluminates?

The hydrogen in aluminium trihydrate may be replaced by an equivalent quantity of various metals. Such compounds are called "*aluminates,*" two of them occurring as minerals, spinel an aluminate of magnesium, Al_2MgO_4, and gahnite an aluminate of zinc, Al_2ZnO_4.

How is aluminium sulphide prepared?

Al_2S_3, aluminium sulphide, is obtained when vapor of carbon disulphide is passed over alumina at red heat. This sulphide is instantly decomposed by water with the evolution of sulphuretted hydrogen.

How is aluminium sulphate produced?

$Al_2(SO_4)_3,18H_2O$, aluminium sulphate, is formed:—

(1) From aluminium hydrate and dilute solution of sulphuric acid, then evaporating;

(2) On a large scale by treating clay with sulphuric acid.

What are its properties?

Its thin pearly plates, soluble in 2 parts of water, have a sweet astringent taste and acid reaction. At a red heat it is decomposed. It combines with the sulphates of potassium, sodium, ammonium, and the other alkali metals, forming double salts of great importance.

What are the alums?

Common alum, the source of all the preparations of alumina, is $AlK(SO_4)_2 12H_2O$, manufactured from clay. We may replace K by Na, Ag, Tl, Cs, Rb, or Al by Cr, Ga, In, Fe, or Mn, and in every case we obtain a salt having 12 molecules of water, crystallizing in regular octahedrons. Potassium and ammonium alums are both important, and are used as mordants in dyeing and in the preparation of skins, etc.

What are the phosphates of aluminium?

The normal salt, $AlPO_4$ or $Al_2(PO_4)_2$, is prepared from a neutral solution of alum with sodium phosphate. It occurs as the mineral navellite, $2Al(PO_4)_2Al_2(OH)_6 + 9H_2O$, containing small quantities of Cl and F; and as the mineral turquoise, $Al_2(PO_4)_2, Al_2(OH)_6 + 2H_2O$.

Where are the silicates of aluminium found?

They occur in a great number of crystalline minerals, but most abundantly as feldspar. Granite, porphyry, trachyte, and other ancient unstratified rocks consisting mainly of this mineral, suffer complete decomposition by natural agencies and are converted into a soft friable mass of earthy matter. This is the origin of clay.

Feldspar may be separated from quartz and mica in granite by grinding and washing. It is used in the manufacture of porcelain. The composition assigned to unaltered feldspar is:—

$$Al_2O_3K_2O, 6SiO_2 \text{ or } Al_2K_2Si_6O_{16}.$$

What is kaolin?

Pure porcelain clay, or kaolin, is a hydrous aluminium silicate, $H_2Al_2Si_2O_8 + H_2O$, derived from feldspar rocks by atmospheric processes called weathering. *Fire-clays* contain large admixtures of silica.

Clays containing calcium carbonate are called *marls.*

Clays are called "*acid*" or "*basic*" according to the excess of SiO_2 or Al_2O_3 in their composition.

The plasticity of clay is due to the chemically combined water, and is rendered less dependent on the amount of alumina, calcium, and magnesium present by heating to high temperature, as the combined water is thus expelled and the clay loses its plasticity and becomes hard and porous.

Give the tests for aluminium compounds.

(1) With *cobaltic nitrate* heated before the blowpipe they give an infusible mass of characteristic blue color;

(2) *Caustic potash* or *soda* gives a bulky gelatinous precipitate of aluminium hydrate freely soluble in an excess of the alkali;

(3) *Ammonia* produces a similar precipitate insoluble in an excess of the reagent;

(4) The *alkaline carbonates* and *ammonium carbonate* give precipitates of the hydrate, liberating carbon dioxide gas.

How is porcelain manufactured?

The manufacture of porcelain and earthenware is of very ancient origin. Clays, being plastic, are easily moulded and lose their plasticity by heat, becoming hard and porous. In making porcelain the finely powdered kaolin is mixed with water to a thick paste and moulded by a potter's wheel or in moulds. A little feldspar, chalk, or gypsum is added in order to form a fusible silicate in quantity just sufficient to bind the particles more together, and to diminish the contraction which clay undergoes in the fire a quantity of finely divided silica is added. Upon firing, as this process of burning is called, a porous "biscuit ware" is obtained which is afterwards subjected to a glazing process.

The glazing material is generally powdered feldspar mixed to a very thin paste with water. The porous biscuit is dipped into this mixture and withdrawn, and the water permeates the piece, leaving the powder evenly spread upon the surface. It is once more dried and fired at a high temperature. The feldspar, being fusible, melts to a thin, smooth, glassy layer. The ornamentation in gilt and enamel is afterwards applied, the colors used consisting of various metallic oxides: cobalt oxide for blue, chrome oxide for green, etc. Some colors are put on previous to glazing, but the more delicate tints are imparted in a separate firing over the glaze.

How is stoneware made?

Coarse kinds of porcelain are made from impure clays containing oxide of iron and a little lime, to which it owes its partial fusibility. Many recipes are used to impart glaze to stoneware, the simplest being the throwing of common salt into the heated furnace. The salt volatilizes and is decomposed by the silica of the ware and the vapor of water always present. It forms a fusible silicate of sodium, which spreads over the surface of the ware, giving a thin but excellent glaze.

How is earthenware made?

The finest kind is made from a white secondary clay mixed with a considerable quantity of silica. The articles are dried, fired, and dipped into a readily fusible glaze mixture, sometimes containing oxide of lead, then dried and reheated to form a glaze. The ornamental designs in blue and other colors so common on plates and household articles are printed on paper with the enamel pigment mixed with oil and transferred while wet to the unglazed ware. When dry the articles are glazed.

The coarser kinds of earthenware are sometimes covered with a whitish, opaque glaze containing oxides of lead and tin. Such a glaze is liable to be attacked by acids, and is dangerous for culinary purposes.

How are crucibles made?

They are made from clay, free from lime, mixed with sand or ground ware of the same description. Hessian or Cornish crucibles are among the best. Graphite crucibles are made by mixing definite proportions of clay, sand, and graphite, generally about 50 per cent. of the latter. The mixture is carefully ground, thoroughly mixed, and allowed to stand some weeks to expel all air-bubbles, then moulded into shapes and burned.

INDIUM. Symbol **In**. Atomic weight 114.4.

Give the occurrence and preparation of indium.

Indium occurs in a few zinc ores, and is found in the flue-dust of zinc furnaces. It is obtained from the metallic sponge of zinc works. It was discovered by Reich and Ruhter in 1863.

What are the properties of indium?

When reduced from its oxide by metallic sodium it is silver-white, soft, and ductile. When heated to redness in air, it burns with a violet flame, yielding yellow sesquioxide. It is a trivalent element, soluble in strong mineral acids, and is precipitated from solutions by *zinc* and *cadmium*. The spectrum of indium has two indigo-colored lines. It was the observation of this peculiar spectrum that led to the discovery of the metal.

What are the principal indium compounds?

The formulæ of the principal normal indium compounds are as follows :—

Chloride,	$InCl_3$;
Indium and ammonium chloride,	$2NH_4Cl, InCl_3 + H_2O$;
Oxide, yellow,	In_2O_3 ;
Hydroxide,	$In(OH)_3$;
Nitrate,	$In(NO_3)_3$;
Sulphate,	$In_2(SO_4)_3 + 9H_2O$.

The sulphate forms an alum.

GALLIUM. Symbol **Ga**. Atomic weight 69.8.

Give the occurrence, mode of preparation, and properties of gallium.

Gallium occurs in a few zinc blendes, and is obtained by electrolysis from a solution of its oxide in potash or ammonia. It is a hard, white, ductile metal, somewhat malleable, and acquiring a good polish by pressure. Specific gravity 5.9. It melts at 30.1° C., hence liquefies when pressed between the fingers. The melted metal adheres to glass, giving a mirror whiter than mercury. It oxidizes when heated to redness, but does not volatilize. Its bright electric spectrum, showing a brilliant line and a fainter band in the violet, caused its discovery. The existence of a metal having the atomic weight and properties of gallium was predicted, as already mentioned, by Mendelejeff. Its oxide is GaO_3; its sulphate forms an alum, and its chloride is $GaCl_3$ or Ga_2Cl_6.

VIII. METALS OF THE IRON GROUP.

What metals compose the iron group?

Manganese,
Iron,
Cobalt,
Nickel.

What are their characteristics as a class?

These metals form basic oxides as MO, in which they are bivalent, and corresponding sulphates, which unite with the sulphates of the alkali metals, forming double sulphates, isomorphous with those of the magnesium group; *e. g.*, $K_2Fe(SO_4)_2 + 6H_2O$. Manganese and iron also form sesquioxides, which, like alumina, act as weak bases, and their sulphates, like aluminium sulphate, unite with the sulphates of the alkali metals, forming alums isomorphous with common alum; *e. g.*, *potassio-ferric sulphate*, $KFe^{iii}(SO_4)_2 + 12H_2O$ or $K_2(Fe_2)^{vi}(SO_4)_4 + 24H_2O$. The sesquioxides of nickel and cobalt, on the other hand, act as peroxides dissolving in acids with the evolution of hydrogen or chlorine. Manganese and iron likewise form salts which may be supposed to contain the trioxides, MO_3, or in which the metal is sexivalent, therefore analogous to the sulphides in composition, *e. g.*, *potassium ferrate*, K_2FeO_4 or K_2O,FeO_3. Lastly, manganese forms a class of salts, the *permanganates*, $KMnO_4$ or $K_2OMn_2O_7$, analogous in composition to the perchlorates, and isomorphous therewith. In these salts the manganese, like chlorine in the perchlorates, is supposed to be septivalent.

MANGANESE. Symbol **Mn.** Atomic weight 54.8.

Where does manganese occur?

It is tolerably abundant in nature, occurring in many rocks and minerals. Its chief minerals are: pyrolusite, MnO_2; manganite, Mn_2O_3,H_2O; braunite, Mn_2O_3; hausmannite, Mn_3O_4; rhodochrosite, $MnCO_3$. It is widely diffused in small amounts through many minerals, in soil, and in the ashes of some plants.

State its preparation and properties.

It is prepared from the carbonate or oxide by reduction. It is reddish in color, very hard and brittle. When powdered it decomposes water even at low temperatures, and is soluble in dilute sulphuric acid with great energy, freeing hydrogen. It oxidizes easily, is slightly magnetic, and fusible with difficulty.

The *chlorides* of manganese are the dichloride, $MnCl_2,4H_2O$; and the trichloride, Mn_2Cl_6.

Mention the oxides of manganese.

(1) *Monoxide or manganous oxide*, MnO;
(2) *Trimangano-tetroxide or manganoso-manganic oxide*, Mn_3O_4;
(3) *Sesquioxide or manganic oxide*, Mn_2O_3;
(4) *Dioxide or peroxide*, MnO_2.

The first is a strong, the third a weak base, the second and fourth are neutral. There are also several oxides intermediate between the monoxide and dioxide occurring as minerals. Manganese forms two series of oxygen salts, *manganates* and *permanganates*. Their corresponding oxides, MnO_3 and Mn_2O_7, are not known.

State the occurrence, mode of preparation, and properties of the red oxide of manganese.

Mn_3O, probably MnO,Mn_2O_3, *trimangano-tetroxide* or *red oxide of manganese*, occurs in the mineral hausmannite. It is prepared by heating the di- or sesquioxide to whiteness. It is a reddish-brown substance which does not form salts soluble in acids.

How is the peroxide of manganese obtained, and what is its use?

MnO_2, the *peroxide*, occurs as the mineral pyrolusite. It is prepared by calcining the nitrate, and is a black substance insoluble in water, but uniting with stronger bases, as potash, lime, etc., to form *manganates*, *e. g.*, $CaOMnO_2$ or $CaMnO_3$. Great quantities are used in the manufacture of bleaching-powder, oxygen, salts of manganese, and in the manufacture of steel.

What is manganese sulphate?

$MnSO_4,7H_2O$, manganese sulphate, is derived from a solution of the monoxide in sulphuric acid. It is a beautiful rose-colored salt, very soluble, forming a double salt with potassium sulphate. It is used to produce a permanent brown dye.

How is potassium manganate obtained?

The oxide of manganese fused with potash becomes K_2MnO_4, potassium manganate, of a deep green color, very soluble in water, from which green crystals are obtained. In these salts manganese, like chromium in the chromates, is sexivalent.

How is the permanganate of potassium obtained?

Potassium permanganate is obtained :—

(1) By decomposition of potassium manganate in water, forming $K_2Mn_2O_8$ or $K_2O_7Mn_2O_7$:—

$$3K_2MnO_4 + 2H_2O = MnO_2 + K_2Mn_2O_8 + 4KHO.$$

(2) It is commercially prepared from manganese dioxide, potassium chlorate, and potassium hydroxide.

The dark purple crystals thus formed are soluble in water and decomposed by contact with organic matter. It is used to test the presence of organic matter, as a disinfectant, and as a reagent for determining iron in the laboratory. The green and red disinfectants known as *Condy's fluids* are alkaline manganates and permanganates.

State the mode of preparing permanganic acid.

$H_2Mn_2O_8$, permanganic acid, results from distilling potassium permanganate with sulphuric acid. The violet vapors condensing to a green-black fluid with metallic lustre form the acid. It is a most powerful oxidizing agent, instantly setting fire to paper and alcohol.

Give the tests for manganese compounds.

(1) The *fixed caustic alkalies* and *ammonia* give white precipitates insoluble in an excess quickly becoming brown.

(2) *Carbonates of fixed alkalies* and of *ammonia* give white precipitates insoluble in an excess of ammonium carbonate.

(3) *Hydrogen sulphide* has no effect; *ammonium sulphide* gives an insoluble flesh-colored sulphide of manganese.

(4) *Potassium ferro-cyanide* gives a white precipitate.

(5) They are easily detected by the blowpipe. The hot bead of a manganese salt touched to a crystal of sodium nitrate gives amethyst-colored froth, a very delicate test. Also heated on platinum foil with sodium carbonate, it yields a green mass of sodium manganate.

State the uses of manganese.

Two important alloys of manganese and iron are used extensively in the manufacture of steel, viz.: Spiegeleisen, which is cast-iron containing from 10 to 20 per cent. of manganese, and ferro-manganese, which is iron containing 60 to 80 per cent. of manganese. The black oxide is an important agent in the production of chlorine, the preparation of green and red disinfecting manganates, purple glass, and black glazes for earthenware.

IRON (FERRUM). Symbol **Fe**. Atomic weight 56.

Where does iron occur?

Iron, the most important metal, occurs rarely as a mineral. With nickel it is found in all meteorites. As an *oxide* it is of universal presence. The principal oxide ores are magnetite, Fe_3O_4; hematite, Fe_2O_3; limonite, $Fe_2O_3,3H_2O$. It constitutes a great part of the coloring-matter of rocks and soils and is contained in plants. It is an essential component of animal blood and of the water of many springs, etc. As a *sulphide* it occurs in the minerals pyrite, FeS_2, and pyrrhotite,

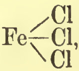
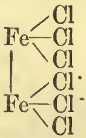
Fe_8S_9, and in combination with other sulphides. As a *carbonate* it is found in the mineral siderite, $FeCO_3$, one of the important ores of iron.

How may iron be prepared?

Pure iron may be prepared in a crucible by fusing 4 parts of fine iron-wire and 1 part of black iron oxide with a cover of flux. The traces of carbon and silicon present in the wire are oxidized by the oxygen of the oxide.

What are the properties of pure iron?

Pure iron has a white color and a perfect lustre. Specific gravity 7.8. It is extremely soft and tough, and the most tenacious of all metals: a wire $\frac{1}{36}$ of an inch in diameter will bear a weight of 60 pounds. The crystalline form is probably the cube. Fusing with difficulty under heat, before becoming liquid it passes into an intermediate pasty state; pieces of iron in this pasty state can be hammered or pressed, called *welding*, into a single mass. Usually a little sand is sprinkled over the heated surfaces to combine with the superficial surface of oxide, forming a fusible silicate, which is subsequently forced out from between the pieces of iron by the pressure applied. It does not oxidize in dry air. Heated to redness it becomes coated with a scale of black oxide; at high white heat it burns brilliantly, forming an oxide. Its combustion in oxygen gas occurs with great ease. The finely divided spongy metal, prepared by reducing the red oxide with hydrogen, takes fire spontaneously in air. Pure water, free from air and carbonic acid, does not tarnish polished iron, but the combined agency of free oxygen and moisture speedily produces rust, which is the hydrated oxide of iron.

At a red heat iron decomposes water, yielding hydrogen and the black oxide of iron. Iron is freely soluble in dilute sulphuric and hydrochloric acids with the separation of hydrogen. Iron is strongly magnetic up to red heat, at which temperature it loses this property. It forms two classes of compounds, the *ferrous* compounds, acting as bivalent, $FeO_3FeCl_2FeSO_4$; and *ferric* compounds, in which, like aluminium, it may be regarded as either triad or tetrad. Ferric chloride may be regarded as $FeCl_3$, , or as Fe_2Cl_6, . The vapor density of this compound, determined by Deville, favors the latter formula.

All commercial iron contains impurities, mainly carbon, with smaller amounts of silicon, manganese, and still smaller amounts of phosphorus and sulphur. Its properties are remarkably affected according to the proportions of these impurities. It is roughly classified as follows: Wrought-iron, or malleable iron, contains less than half a per cent. of these impurities; cast- or pig-iron contains from 2½ to 6 per cent.; steel lies intermediate between these two.

In how many forms does commercial iron appear?

Iron appears in commerce in three forms, as cast-iron, wrought-iron, and steel.

How is cast-iron prepared?

Cast-iron is produced in the *blast furnace.* Internally the furnace shape is like two hollow cones placed base to base, sometimes separated by a hollow cylinder. Air is blown in at the bottom through water-cooled apertures called "twyeres," and the gases produced (containing about 20 per cent. carbon monoxide) are drawn off from the top and utilized to heat the blast from 1400° to 1600° F.

The interior of the furnace is lined with fire-brick. The exterior consists of sheet-iron suitably braced and supported. Alternate layers of flux, limestone, ore, and fuel are fed at the top and descend through the furnace. The upper portion of the furnace is called the *zone of preparation*, and in it moisture, bituminous matter, and carbon dioxide are driven off. Below this is the *zone of reduction*, and it is here that the oxides of iron are reduced to metallic iron by the carbon monoxide gas and incandescent carbon of the fuel. At the lower portion of this zone the spongy iron produced absorbs some carbon from the fuel and becomes more fusible. This portion of the furnace is called the *zone of fusion*, as it is here that the solid reduced iron is converted to liquid iron (with assimilated carbon from fuel). In addition to this the flux (calcite or dolomite) unites with the infusible siliceous elements of the ore, yielding a fusible silicate called "slag." This slag together with the reduced and carburized iron falls to the bottom of the crucible, the lighter slag floating on the cast-iron protecting it from the blast. From the beginning of the fusion zone the iron, in contact with the fuel, takes to itself the metalloids, carbon and silicion, in quantity depending on the temperature and length of time they are in contact, hence the variation of impurities from 2 to 6 per cent. of carbon.

When sufficient iron has accumulated it is drawn off from the crucible hearth and either cast into sand moulds, called "pigs," or into a ladle, to be used direct in Bessemer's process for making steel. The air blown in through the twyeres meets incandescent carbon and immediately forms carbon dioxide, yielding great heat (it is just above the twyeres that the hottest part of the furnace exists, about 4000° F.). The carbon dioxide produced is immediately converted to carbon monoxide, CO: $CO_2 + C = 2CO$, with absorption of heat. The action of the CO as a reducing agent is:—

$$Fe_xO_y + yCO = Fe_x + yCO_2.$$

This CO_2 is reconverted by the C of the fuel into 2CO, etc. The gases drawn off from the furnace top consist of about 60 per cent. nitrogen, the remainder, 40 per cent., consisting variously of CO and CO_2, with a little moisture and ammonia compounds, etc.

What are the varieties of pig-iron?

The varieties of pig-iron are roughly graded as *gray*, *white*, and *mottled*, always crystalline in structure and more or less brittle.

White iron is hard, highly crystalline, and quite brilliant. Its carbon contents are chiefly in a state of combination.

Gray iron is softer, closer-grained, and has its carbon partly in combination and partly as graphite.

Mottled iron is a mechanical mixture of the two.

What is spiegeleisen?

Spiegeleisen is a particularly brilliant and crystalline pig-iron having about 6 per cent. carbon and up to 20 per cent. of manganese. It is used in steel manufacture. The common impurities of cast-iron are silicon, sulphur, and phosphorus, the last two elements being particularly objectionable. The sulphur renders the metal "*red-short*" or "*hot-short*," or brittle at red temperature, while phosphorus renders it "*cold-short*" or brittle when cold.

To what uses are the gray and white iron adapted?

Gray iron is used for foundry purposes and for the manufacture of steel, especially by Bessemer's process. *White iron* is used for forge purposes, for the manufacture of wrought-iron by puddling, and in the manufacture of steel.

How is wrought-iron produced?

Wrought-iron is sometimes prepared directly by heating the iron ore with charcoal in a furnace and purifying the pasty product from adhering slag and fuel by hammering or squeezing, known as "blooming." Another method is to refine cast-iron in refineries or puddling furnaces. The impurities, carbon, silica, manganese, and phosphorus, are removed by heating the mass with oxides of iron. The carbon becomes carbon dioxide and the other impurities are removed in the slag. The iron becomes pasty and is rolled into bars. This process is technically called "puddling."

Wrought-iron is tough, fibrous in structure, and almost infusible. At a red heat it can be worked and welded by hammering or rolling, whence its great value as a construction material.

How is steel produced?

Steel may be made in several ways :—

(1) *Cement steel* is made by carbonizing malleable iron. This is accomplished in furnaces enclosing rectangular boxes of siliceous material containing bars of wrought-iron packed in charcoal. Steel thus produced, called "blister steel," is made homogeneous by melting it in crucibles

after which it is cast into small ingots. The cementation process is also used for hardening the surface of armor plates.

(2) *Crucible steel* is a crucible-melted mixture of irons of varying carbon-contents with or without carbonizing or decarbonizing materials, according to the product desired.

What are the uses of crucible steel?

The high-grade carbon steels are used for tools, fire-arms, springs, etc. The special grade steels are employed as chrome steel, tungsten steel, and manganese or Franklinite steel, etc.

(3) *Open-hearth steel*, acid process: By melting pig-iron and ore, known as "pig and ore," or Siemen's process; or by melting pig-iron and scrap-iron and steel, known as Siemen-Martin's process, on the hearths of a reverberatory furnace. When the impurities, silicon, manganese, and carbon, are oxidized and removed the residue is then carbonized to the desired extent by the addition of suitable recarbonizers, viz., spiegeleisen, ferro-manganese, or by filtering the decarbonized mass of melted metal over carbon filters, by which carbon in required quantity is taken up. These low-carbon steels are especially suited for armor-plate, fire-boxes, tanks, tires, and construction material.

(4) *Bessemer steel*, acid process: This method decarburizes molten gray iron by means of blasts of air. The molten iron is contained in a "converter" of wrought-iron lined with brick having twyere holes at the bottom, revolving on horizontal trunnions, one of which is hollow and conveys the blast. The capacity of this vessel is 15 tons or greater. The molten pig, either direct from the blast furnace or remelted in a "cupola" furnace, is run into the "converter," which is half-way turned down. As the "converter" is turned up it automatically opens the air valve and the air is driven through the melted metal, oxidizing out the impurities, silicon, manganese, and carbon. The heat necessary for the process is furnished by the oxidation of impurities, carbon, silicon, and manganese. The operation is guided by the appearance of the flame. When the molten metal is free from impurities the converter is turned down and the metal recarbonized as before by the addition of spiegeleisen, ferro-manganese, or carbon filters. It is then cast into ingots to be roasted into the final product. This steel is especially adapted to the manufacture of rails and construction material.

In these processes the steel produced contains all the phosphorus of the ore. This phosphorus can only be eliminated from the molten metal by means of a basic slag, the presence of which in an acid furnace would rapidly combine with the furnace-lining, forming a fusible slag and destroying the furnace. The basic open-hearth and the basic Bessemer processes are essentially the acid processes conducted in furnaces or converters having basic linings. The steels thus produced are called respectively basic open-hearth and basic Bessemer steel. Phosphorus, the most objectionable impurity of iron, is removed by the basic slag, which can only be used in furnaces having a basic lining.

How is ferrous chloride prepared?

$FeCl_2$, ferrous chloride, is procured by dissolving iron in hydrochloric acid. The solution concentrated and evaporated yields green crystals of $FeCl_2,4H_2O$, which are very soluble and deliquescent, oxidizing rapidly in air. It is used in metallurgy.

How is ferric chloride obtained?

Fe_2Cl_6, ferric chloride, is obtained by dissolving ferric oxide in hydrochloric acid. By concentration and evaporation the solution yields red crystals—hydrated—very soluble in water and alcohol. It forms double salts with potassium and ammonium chlorides, and is used as a reagent in the laboratory and as a material to stop bleeding.

State the mode of preparing ferrous iodide?

FeI_2, ferrous iodide, is obtained by digesting iodine with water and metallic iron. The solution is pale green and yields crystals resembling the chloride. It rapidly oxidizes in contact with air. Medicinally, it is important.

Fe_2I_6, ferric iodide, is yellowish-red and soluble.

Mention the oxides of iron.

The oxides of iron are—
(1) *Ferrous oxide*, FeO;
(2) *Ferric oxide*, Fe_2O_3;
(3) *Triferro-tetroxide*, $Fe_3O_4(FeO,Fe_2O_3)$;
(4) *Trioxide*, supposed to exist in ferrates, but not isolated, FeO_3.

What is ferrous oxide?

FeO, ferrous oxide or monoxide, isomorphous with magnesia, zinc oxide, etc., is a powerful base neutralizing acids.

How is ferric oxide produced?

Fe_2O_3, ferric oxide or sesquioxide, occurring extensively as the minerals hematite, Fe_2O_3, and limonite, $Fe_2O_3,3H_2O$, is prepared:—

(1) By calcining ferrous sulphate;

(2) By precipitating ferrous chloride or sulphate with an excess of ammonia, washing, drying, and igniting. The yellow-brown hydrate produced is a fine powder having a red color. Unaltered by fire, it is easily reduced at high temperatures by carbon or hydrogen. It forms with acids a series of reddish salts of acid reaction and astringent taste. It is not acted upon by the magnet.

What uses has this oxide?

As an ore of iron it is important. It is the pigment known as Venetian red. It is used as a polishing material for glass and precious metals;

as jewellers' rouge and crocus powder. The hydrated oxide, $Fe_2O_3,3H_2O$ or $Fe_2(OH)_6$, is used for purifying coal-gas, and as an antidote for arsenical poisoning.

State the occurrence and mode of preparing black oxide of iron.

Fe_3O_4, triferro-tetroxide, ferroso-ferric oxide, also called *magnetic oxide* and *lodestone*, is one of the most valuable of the iron ores, occurring as the mineral magnetite, *lodestone* itself being a magnet. It is precipitated from a properly proportioned mixture of ferrous and ferric salts by an excess of alkali, and boiling the mixed hydroxides. A black sandy substance consisting of minute crystals of magnetic oxide is thus obtained.

Mention some of the ferrates.

Potassium ferrate,	K_2FeO_4 or K_2O,FeO_3;
Barium ferrate,	$BaFeO_4$ or BaO,FeO_3.

Neither the acid, H_2FeO_4, nor oxide, FeO_3, is known in a separate state.

What is ferrous sulphate?

$FeSO_4$, ferrous sulphate, *green vitriol*, *iron vitriol*, or *copperas*, occurs as the mineral melanterite, but is prepared commercially by the contact of air and moisture with iron pyrites. The salt produced is dissolved out by water, and the solution crystallized. It is obtained in large quantities as a by-product from galvanizing iron. The "pickle" for cleansing the iron previous to its being coated with zinc is dilute sulphuric acid. This acid gradually becoming saturated with iron yields crystals of iron sulphate. It is also a by-product in copper and silver works. It generally crystallizes with $7H_2O$, sometimes with 4 or $2H_2O$. It is green in color, efflorescent, and soluble in 2 parts of cold water. It forms double salts with potassium and ammonium sulphates. With tannin or a solution of galls it yields a deep black color. It is used in the manufacture of inks and as a disinfectant.

What is ferric sulphate?

$Fe_2(SO_4)_3$, or $Fe_2O_3,3SO_3$, ferric sulphate, occurs in several minerals as a basic sulphate. It forms alums with potassium and ammonium :—

$$Fe^{iii}K(SO_4)_2,12H_2O.$$

What are the iron nitrates?

$Fe(NO_3)_2$, ferrous nitrate ;
$Fe_2(NO_3)_6$, ferric nitrate, used in dyeing.

How is ferrous carbonate prepared?

$FeCO_3$, ferrous carbonate, occurs as the mineral siderite, an important ore of iron known as *spathose iron ore*, *iron spar*, *clay-iron stone*. It is often found in mineral waters, being soluble in an excess of carbonic acid.

It is prepared from a ferrous salt and an alkaline carbonate, making a white precipitate which cannot be washed and dried without absorbing oxygen and losing carbonic acid.

The *phosphates* of iron are all insoluble.

What are the sulphides of iron?

Several compounds of sulphur and iron are known. The most important are:—

Monosulphide, FeS; *Bisulphide*, FeS_2.

FeS, mono- or ferrous sulphide, is produced by heating iron and sulphur. It is black, brittle, magnetic, and soluble in dilute acids, yielding sulphuretted hydrogen gas.

FeS_2, bi- or ferric sulphide, occurs as the minerals pyrite and marcasite. The brass-yellow colored crystals of pyrite, formerly called *fool's gold*, are not attracted by the magnet. They are hard and insoluble in dilute acids. Pyrite is one of the chief materials for manufacturing sulphuric acid. The magnetic sulphide of iron, Fe_7S_8, occurs as the mineral pyrrhotite.

What other compounds of iron occur?

Compounds with *carbon*, *phosphorus*, and *silicon* exist, but little is known respecting them in a definite state. The carbonide is contained in cast-iron and steel, communicating ready fusibility. The compound with silicon also occurs in cast-iron.

What are the tests for iron compounds?

Ferrous salts are distinguished as follows:—

(1) *Caustic alkalies* and *ammonia* give nearly white precipitates insoluble in an excess of the reagent, rapidly becoming green and ultimately brown by exposure to air;

(2) *Carbonates of potassium, sodium*, and *ammonium* give precipitates of white ferrous carbonate, also subject to change in color;

(3) *Hydrogen sulphide* gives no precipitate;

(4) *Ammonium sulphide* yields black ferrous sulphide, soluble in dilute acids;

(5) *Potassium ferrocyanide* yields a white precipitate becoming deep blue by exposure to air.

The *ferricyanide* gives at once a deep blue precipitate.

Ferric salts are distinguished as follows:—

(1) *Caustic fixed alkalies* and *ammonia* give foxy-red precipitates of hydroxide, insoluble in an excess;

(2) The *carbonates* behave in a similar manner;

(3) *Hydrogen sulphide* gives a nearly white precipitate of sulphur and reduces the ferric oxide to ferrous;

(4) *Ammonium sulphide* gives a black precipitate slightly soluble in an excess;

(5) *Potassium ferrocyanide* yields Prussian blue;

(6) *Tincture* or *infusion of gall-nuts* gives a bluish-black color with the most dilute solution of ferric salts;

(7) Sulphocyanide of ammonium gives a blood-red precipitate with the most dilute solution.

All compounds of iron heated on charcoal with sodium carbonate yield a magnetic mass.

COBALT. Symbol **Cl.** Atomic weight 58.3.

How does cobalt occur?

Cobalt is a comparatively rare metal. It occurs as sulphides, arsenides, arsenates, etc. Its minerals are linnæite, Co_3S_4; smaltite, $(CoFeNi)As_2$; cobaltite, $CoS_2 + CoAs_2$; erythrite, $Co_3As_2O_8 + 8H_2O$. It is generally present in meteorites.

What are the properties of cobalt?

Cobalt is a reddish-white, brittle, tenacious solid having a high melting-point. It is unchanged by air and but feebly attacked by dilute acids. It is strongly magnetic, and forms two classes of salts, cobaltous and cobaltic, the latter class being very unstable.

State the properties and uses of cobaltic chloride.

$CoCl_2$, cobaltous chloride, dichloride of cobalt, prepared from the oxide and hydrochloric acid, forms a deep rose-red solution, depositing hydrated crystals of the same color. These are transformed by heat to anhydrous blue crystals, which in contact with water dissolve to a red liquid.

A dilute solution is used as *blue sympathetic ink*. Characters written on paper are invisible from paleness of color until the salt has been rendered anhydrous by heat, when the letters appear blue. On laying it aside moisture is absorbed and the writing disappears. Green sympathetic ink is a mixture of the chlorides of cobalt and nickel.

Give the oxides of cobalt.

CoO, monoxide of cobalt, cobaltous oxide; Co_2O_3, sesquioxide, cobaltic oxide; Co_3O_4, cobaltoso-cobaltic oxide.

What is the nature of cobaltic salts?

Cobaltic oxide is a weak base soluble in acids, forming brown solutions easily decomposed. The most stable salt is the acetate. With potassium and ammonium it forms double salts which are more stable.

What are the tests for cobalt compounds?

COBALTOUS SALTS:—

(1) *Potassium hydroxide* gives a blue precipitate turning red.

(2) *Ammonia* gives a blue precipitate turning brown.

(3) *Sodium carbonate* yields a pink precipitate.
(4) *Potassium ferrocyanide* gives a grayish-green precipitate.
(5) *Potassium cyanide* gives a yellow-brown precipitate soluble in an excess.
(6) *Ammonium sulphide* yields a black precipitate insoluble in hydrochloric acid.

COBALTIC SALTS :—
(1) *Potassium hydroxide* forms a dark brown precipitate.
(2) *Ammonia* gives a brownish-red solution.
(3) *Fixed alkaline carbonates* yield a green solution.
(4) *Ammonium sulphide* forms a black precipitate.

The blowpipe-test for cobalt compounds is extremely delicate. The smallest amount dissolved in a borax bead yields a beautiful blue color.

Give the uses of cobalt.

It is extensively used as a pigment for coloring glass and porcelain.

Smalt's blue is the silicate.

Thenard's blue and *cobalt ultramarine* are compounds of cobalt and aluminium salts.

Rinmann's green is the oxides of cobalt and zinc.

A properly proportioned mixture of the oxides of cobalt, manganese, and iron imparts a fine black color to glass.

The soluble salts are used as sympathetic ink and for plating purposes; the articles so treated are sold as superior nickel plate.

NICKEL. Symbol Ni. Atomic weight 58.8.

How does nickel occur?

It is fairly abundant as the minerals millerite, NiS; niccolite, Ni_2As_2; as a silicate with cobalt in smaltite, (CoFeNi)As_2; and as annabergite, $Ni_3As_2O_8 + 8H_2O$.

It is also found in all meteorites.

State its mode of preparation and properties.

It may be obtained :—
(1) From its oxalate and charcoal heated to a high degree in a crucible;
(2) By the reduction of its oxide by hydrogen at a high heat.

Nickel is a white malleable solid, specific gravity 8.8, having a high melting-point. It is less oxidizable than iron and but little attacked by dilute acids. It is strongly magnetic.

How is nickel chloride prepared?

$NiCl_2$, nickel chloride, is prepared by dissolving nickel oxide or carbonate in HCl. The green solution deposits green hydrated crystals, turning yellow by heat.

What is nickel sulphate?

$NiSO_4$, nickel sulphate, the most important of nickel salts, occurs in green, prismatic crystals, $NiSO_4,7H_2O$, soluble in three parts of water. It forms beautiful double salts with the sulphates of potassium and ammonium:—

$$NiK_2(SO_4)_2,6H_2O \text{ and } Ni(NH_4)_2(SO_4)_2,6H_2O.$$

Nickel also forms an *oxalate*, *carbonate*, etc.

Nickel salts, when hydrated, usually have a beautiful green color; in the anhydrous state they are yellow.

Give the tests for nickel compounds.

(1) *Caustic alkalies* give an apple-green precipitate of the hydroxide insoluble in an excess.

(2) *Ammonia* gives a similar precipitate soluble in an excess, and changing the solution to a purplish-blue.

(3) *Potassium and sodium carbonates* give pale green precipitates.

(4) *Potassium ferricyanide* yields a greenish-white precipitate.

(5) *Potassium cyanide* gives a green precipitate, soluble in an excess, changing from green to an amber-colored solution.

(6) *Ammonium sulphide* yields a black precipitate slightly soluble in an excess, which changes the solution to a dark brown color.

What are the uses of nickel?

The uses of nickel are extensive.

(1) *Nickel-plating.* The salt employed is the double sulphate of nickel and ammonium, which may be deposited on iron, steel, copper, brass, and other metals.

(2) *Alloys: Coins*, nickel with copper or zinc; *German silver*, nickel with copper and zinc. Other alloys are made for special purposes by varying the proportions and the addition of small amounts of other metals.

IX. METALS OF THE CHROMIUM GROUP.

What are the metals of the chromium group?

Chromium,
Molybdenum,
Tungsten,
Uranium.

What are their characteristics?

These metals are hexads, their highest oxides, which are of acid character, having the composition MO_3. They also form lower oxides, MO_2, M_2O_3, M_3O_4, and MO, more or less basic and analogous in composition to the basic oxides of manganese, iron, cobalt, and nickel. Chromium, molybdenum, and tungsten form hexfluorides analogous to the highest oxides, and uranium forms an oxychloride, UO_2Cl_2. As metals they have very little importance; their compounds, however, are very useful.

CHROMIUM (*chroma*, color). Atomic weight 52.4.
Symbol **Cr.**

Where does chromium occur?

It is not very abundant. The mineral chromite, $FeCr_2O_4$, which is its chief ore, is its main source. It is obtained by reducing its oxides by heat and carbonaceous matter. Almost infusible in hardness, it is soluble in dilute hydrochloric acid. When crystalline it resists the action of acids, even aqua regia. It imparts hardness to steel.

How is chromous chloride prepared?

$CrCl_2$, chromous chloride, dichloride of chromium, is prepared by the action of hydrogen on trichloride of chromium, and dissolving the residue in water. This process yields a blue solution which absorbs oxygen from the air with extraordinary energy, and acquires a deep green color, passing into chromium oxychloride. It is one of the most powerful reducing agents known.

Mention the chromium fluorides.

Chromium trifluoride, Cr_2Cl_6;
Chromium hexfluoride, $CrCl_6$.

Give the oxides of chromium.

CrO, Cr_3O_4, Cr_2O_3, CrO_2, and CrO_3.

CrO, monoxide or chromous oxide, is a powerful base forming pale blue salts.

Cr_3O_4, trichromic tetroxide, corresponds to the magnetic oxide of iron, but is not salifiable.

How is chromium sulphate used?

Chromic sulphate, $Cr_2(SO_4)_3$, forms double salts with sulphates of potassium and ammonium, making *alums*. It is used to impart a fine green color to glass and as an enamel. The crystalline sesquioxide is used on the surface of razor straps.

CrO_3, chromium trioxide, is the most important of the oxides. It exists as crimson-red, prismatic crystals, deliquescent and soluble in water, forming chromic acid, H_2CrO_4, from which a great variety of chromates may be derived.

For what is potassium dichromate used?

Potassium chromate is K_2CrO_4 or K_2O,CrO_3.

Potassium *dichromate* or pyrochromate, K_2CrO_4,CrO_3, exists as red tabular crystals soluble in ten parts of water. Immense quantities of this salt are used in the arts:—

(1) In dyeing and calico-printing;
(2) In the preparation of chrome paints;
(3) As an oxidizing agent in bleaching discolored fats and oils;
(4) For battery use;
(5) In photography.

A gelatine film saturated with this salt is rendered insoluble by action of light. A photograph taken on such a film may be made to stand out in actual relief by dissolving away the unattacked parts, and may then be copied by electroplating or in type-metal, or transferred to lithographic stone. This is the basis of the processes of photographic printing, such as heliotypes, autotypes, photolithographs, etc.

Potassium trichromate is $K_2O,3CrO_3$.

How is lead chromate prepared?

Lead chromate, $PbCrO_4$, is prepared by uniting solutions of lead acetate and potassium pyrochromate, and filtering off the yellow precipitate of *chrome-yellow*. By boiling with potassium hydroxide it is converted into a basic chromate, $PbCrO_4,PbO$, rivalling vermilion in color, *chrome-red*. A mixture of the two yields *chrome-orange*. It is used as a pigment and dye-stuff.

What are the tests for chromium compounds?

Chromium compounds give with

(1) *Ammonium sulphide*, a gray-green precipitate;

(2) *Caustic fixed alkalies*, a precipitate of hydroxide soluble in an excess of alkali;

(3) *Ammonia*, the same, but nearly insoluble;

(4) *Carbonates of potassium, sodium, and ammonium*, a green precipitate of hydroxide slightly soluble in an excess.

The *chromic* compounds yield with

(5) *Barium salts*, a pale yellow precipitate; *lead salts*, a bright yellow; *mercurous salts*, a brick-red; and *silver salts*, a crimson color.

(6) The blowpipe-test is the green color imparted to a borax bead in both the oxidizing and the reducing flames.

MOLYBDENUM. Symbol **Mo**. Atomic weight 96.

How does molybdenum occur?

This rare metal occurs in small quantities as molybdenite, MoS_2; and wulfinite, $PbMoO_4$.

How is it prepared?

It is prepared by reducing, at an intense heat, molybdic oxide in a charcoal-lined crucible. It is a brittle, white metal, exceedingly infusible, and oxidizing when heated in the air. Specific gravity 8.6.

What are its compounds?

It forms complicated compounds. Its leading oxide, MoO_3, and molybdic acid, H_2MoO_4, are analogous to corresponding oxides and acids of chromium and sulphur. Its salt, *ammonium molybdate*, is an indispensable reagent in the laboratory for the determination of phosphorus in the exact analyses of iron ores and fertilizers.

What are the chlorides of molybdenum?

The chlorides of molybdenum are: $MoCl_2$, $MoCl_3$ or Mo_2Cl_6, $MoCl_4$, $MoCl_5$ or Mo_2Cl_{10}, called respectively, di-, tri-, tetra, and penta- chlorides.

Give the oxides of molybdenum.

MoO, monoxide or molybdous oxide;
MoO_2, dioxide or molybdic oxide;
MoO_3, trioxide, commonly called *molybdic acid.*

Give the sulphides of molybdenum.

The *sulphides of molybdenum* are MoS_2, MoS_3, and MoS_4; the di-, tri-, and tetra- sulphides.

TUNGSTEN. Symbol **W**. Atomic weight 184.

How does tungsten occur?

It is rare, but more abundant than molybdenum, occurring as the minerals wolframite, $FeWO_4$; scheelite, $CaWO_4$; and wulfenite, $PbWO_4$. It is obtained by reducing its oxide with hydrogen, and is then found to be a white, hard, brittle metal, burning to an oxide when heated in the air.

Give the chlorides of tungsten.

WCl_2, WCl_4, WCl_5, WCl_6. *Bromides and fluorides* of tungsten also exist.

What are the oxides of tungsten?

WO_2, WO_3, W_2O_5. All possess acid properties, forming *tungstates.*

How are some tungsten compounds used?

The tungstates of potassium and sodium are sometimes used as mordants in calico-printing, and also for rendering muslin and other light fabrics non-inflammable.

The *sulphides of tungsten* are WS_2 and WS_3.

URANIUM. Symbol **U**. Atomic weight 239.

How does uranium occur?

Uranium, one of the rarer metals, occurs in several minerals, such as uraninite (pitchblende), which is its principal ore. It is obtained by decomposing its chloride with metallic potassium. Uranium is silver-white in color, it does not decompose water, but burns to a green oxide. It unites violently with sulphur and chlorine, and forms two classes of compounds, the uran*ic* and the uran*ous.*

Give some of the compounds of uranium.

Uranous chloride, UCl_4;
Uranous bromide, UBr_4;
Uranous oxide, UO_2;
Uranic oxychloride, UO_2Cl_2;
Uranous fluoride, UF_4;
Uranoso-uranic oxide, used for staining glass black, $U_3O_8 = UO_2,2UO_3$;
Uranic oxide, UO_3;
Uranic tetroxide, UO_4.

Uranic oxide, UO_3, unites with basic metallic oxides, forming salts called uranates, the most important of which is *sodium uranate*, Na_2UO_4. It is much used for imparting a yellow fluorescent color to glass (canary glass), and as a yellow pigment for glazing porcelain.

Uranic nitrate and acetate are useful laboratory reagents.

How are the salts used?

(1) In enamel-painting;
(2) In glass-staining;
(3) In photography.

X. METALS OF THE TIN GROUP.

What are the metals of the tin group, and their characteristics?

Tin,
Titanium,
Zirconium,
Thorium.

These metals are tetrads, like silicon, forming volatile tetrachlorides; also tetrafluorides, which unite with other metallic fluorides, forming double salts analogous to the silicofluorides in composition and isomorphous with them.

TIN (STANNUM). Symbol Sn. Atomic weight 117.8.

Where is tin found?

Tin, one of the useful metals, occurs in a few mineral species. Its ore is cassiterite (tin-stone), SnO_2. Tin is rarely found as a sulphide. It is obtained by the reduction of its oxide by carbon in furnaces:—

$$2SnO_2 + 2C = Sn_2 + 2CO_2.$$

What are the properties of tin?

Tin is a white metal, soft, specific gravity 7.3, very malleable, ductile, but not tenacious. At 200° C. it becomes brittle and may be powdered.

It melts at 235° C. When bent or twisted it emits a peculiar crackling noise, called the "cry" of tin, caused by the friction of interlaced crystals. It is but little acted upon by air and water, but oxidizes readily when heated above its melting-point. It is soluble in hydrochloric acid, emitting hydrogen. It forms two classes of salts:—

The *stannous* acting as bivalent;
stannic " " quadrivalent.

Give the mode of preparation and properties of stannous chloride.

$SnCl_2$ or Sn_2Cl_4, stannous chloride or dichloride, is prepared in the anhydrous state by distilling a mixture of calomel and powdered tin. This chloride is gray, resinous-looking, fusible below redness and volatile at a high temperature. The hydrated chloride, $SnCl_2,2H_2O$, presents needle crystals freely soluble in water. It is employed in solution as a deoxidizing agent, reducing salts of mercury and other metals of the same class. It forms crystallizable double salts with alkali metal chlorides, as $SnCl_2,2KCl$.

For what is it used?

(1) It used as a reagent;
(2) As a mordant in dyeing and calico-printing;
(3) As an "antichlor."

How is stannic chloride prepared?

$SnCl_4$, stannic chloride or tetrachloride, may be prepared from:—
(1) Chlorine and metallic tin;
(2) By distilling one part of tin and five parts of mercuric chloride.
It is a thin, colorless, mobile liquid. It boils at 120° C.; fumes in air; and may be solidified by mixing with one-third part of water to a soft fusible mass, called *butter of tin.* It forms crystals of $SnCl_4,5H_2O$. It has value in dyeing for brightening and *fixing* red colors. Tin forms fluorides, which unite with other metallic fluorides, forming *stannofluorides*, isomorphous, with corresponding silicofluorides, titanofluorides, and zircofluorides.

Give the oxides of tin.

SnO, Sn_2O_3, SnO_2.

SnO, stannous oxide or monoxide, is soluble in acids, forming *ous* salts.

SnO_2, stannic oxide or dioxide, occurs as the common ore of tin, cassiterite. It may be obtained by heating tin in air. It is used under the name of *putty powder*, to polish plate. It forms stannic acid, H_2SnO_3, and metastannic acid, $H_{10}Sn_5O_{15}$.

For what is sodium stannate used?

Sodium stannate, Na_2SnO_3, is an important mordant in calico-printing.

Give the sulphides of tin.

SnS, tin monosulphide.

SnS_2, tin bisulphide, known as *mosaic gold*, is obtained by fusing a mixture of 12 parts of tin, 6 parts of mercury, 6 parts of ammonium chloride, and 7 parts of sulphur. The brilliant gold colored scales thus produced are used for bronzing plaster casts.

Give the tests for tin compounds.

Stannous compounds:—

(1) *The fixed caustic alkalies* yield a white precipitate soluble in an excess of the reagent.

(2) *Ammonia* and *carbonates of potassium*, *sodium*, and *ammonium* yield a white precipitate nearly insoluble in an excess.

(3) *Hydrogen sulphide* and *ammonium sulphide* give a black-brown precipitate soluble in ammonium sulphide containing excess of sulphur, from which solution it is reprecipitated as a yellow sulphide by acids.

(4) *Chloride of gold* gives the "*purple of Cassius.*"

Stannic salts:—

(1) *Fixed caustic alkalies* give a white precipitate soluble in an excess.

(2) *Ammonia* and alkaline carbonates yield a white precipitate slightly soluble in an excess.

(3) *Ammonium carbonate* gives an insoluble white precipitate.

(4) *Hydrogen sulphide* yields a yellow precipitate.

(5) *Ammonium sulphide* yields a yellow precipitate soluble in an excess of the sulphide.

Enumerate the uses of tin.

Its use is extensive:—

(1) *Tinned plate*, which is iron covered with tin;
(2) *Pewter* and *Britannia metal*, tin hardened with a little antimony;
(3) Cooking-vessels of copper, usually lined with tin;
(4) Thin sheets, as tin-foil;
(5) Common mirrors backed with tin amalgam;
(6) Tin salts in calico-printing and dyeing;
(7) Bronze, plumber's solder, etc.;
(8) Lining for lead pipes.

TITANIUM. Symbol **Ti**. Atomic weight 48.

How does titanium occur?

One of the rarer metals, titanium occurs as the minerals rutite, TiO_2, and brookite, TiO_2; and in various titaniferous iron ores.

How is it prepared?

By heating together titanium oxide, potassium fluoride, and potassium. It has a remarkable affinity for nitrogen and when heated in air it absorbs both oxygen and nitrogen.

What compounds does it form?

It forms two classes of compounds, *titanous* and *titanic.*

Give the chlorides of titanium.

Ti_2Cl_6, titanous chloride; $TiCl_4$, titanic chloride. It forms corresponding fluorides and double salts called *titanofluorides*, analogous to the corresponding salts of silicon and zirconium.

Give the oxides of titanium.

The oxides of titanium are Ti_2O_3, sesquioxide or titanous oxide, and TiO_2, dioxide or titanic oxide. It forms two acids, titanic and metatitanic acid, similar to stannic and metastannic acids.

How is titanium objectionable and how useful?

The occurrence of titanium in iron ores renders the blast furnace process difficult in the furnaces. It sometimes unites with nitrogen and carbon to form nitrocyanide of titanium, $Ti(CN)_2+3Ti_3N_2$, looking very much like metallic copper. The oxide, TiO_2, has limited use in imparting a yellow tint to porcelain.

ZIRCONIUM. Symbol **Zr.** Atomic weight 90.

Where is zirconium found?

This metal, rarer than titanium, occurs as the mineral zircon, $ZiSiO_4$, and in a few rare minerals, such as fergusonite, endialyte, etc.

What are the properties of zirconium?

It exists in three states, amorphous, crystalline, and graphitoidal.

Amorphous zirconium burns when heated in air to an oxide.

Crystalline zirconium is in the form of hard brittle scales resembling antimony in lustre and color. It burns in air at a high temperature, and takes fire at a red heat in chlorine gas.

Graphitoidal zirconium exists as steel-gray scales.

What use has zirconium?

The mineral zircon is used as a gem known as *hyacinth.* The oxide, ZrO_2, has a limited application for illuminating purposes. Cotton fabric is saturated with zirconium oxide and then ignited. The cotton burns away, leaving a network of zirconium oxide, which becomes incandescent by heat from gas flame and emits light.

THORIUM. Symbol **Th.** Atomic weight 231.5.

How does thorium occur?

The very rare metal thorium is found as a silicate in the mineral thorite and in a few other scarce minerals, as euxenite, etc. It is a gray powder acquiring metallic lustre by pressure, specific gravity 7.66–7.79, insoluble in water, soluble in nitric and hydrochloric acids, but not attacked by caustic alkalies.

Give the compounds of thorium.

ThO_2, thorium oxide, thoria; $ThCl_4$, thorium chloride; $Th(SO_4)_2$, thorium sulphate, which forms a double sulphate with potassium :—

$$ThK_4(SO_4)_4,2H_2O.$$

METALS OF THE ANTIMONY GROUP.

Name the metals of the antimony group.

Vanadium,	Tantalum,
Antimony,	Niobium.
Bismuth,	

What are their characteristics?

These metals act like phosphorus either as a triad or pentad, and if further compared with the non-metals nitrogen, phosphorus, and arsenic, they are seen to form a group of elements each of which is clearly related to the others through a regular gradation of properties.

This fact is indicated in the following table :

	Atomic weights.	Specific gravity.	Oxides.		Acids.	
Nitrogen . .	14	—	N_2O_3.	N_2O_5.	HNO_3.	
Phosphorus .	31	1.837	P_2O_3.	P_2O_5.	HPO_3.	H_3PO_4.
Vanadium . .	51.5	5.5	V_2O_3.	V_2O_5.	HVO_3.	H_3VO_4.
Arsenic . . .	75	5.7	As_2O_3.	As_2O_5.		H_3AsO_4.
Niobium . .	94	—		Nb_2O_5.	$HNbO_3$.	
Antimony . .	120	6.7	Sb_2O_3.	Sb_2O_5.	$HSbO_3$.	
Tantalum . .	182	—		Ta_2O_5.	$HTaO_3$.	
Bismuth . .	208	9.82	Bi_2O_3.	Bi_2O_5.	$HBiO_3$.	

The antimony group appears to be on the dividing-line between the non-metallic and metallic elements.

VANADIUM. Symbol **V.** Atomic weight 51.2.

How does this very rare metal occur?

It is widely diffused in rock as the minerals vanadinite, $Pb_5(VO_4)_3$; descloizite, $(Pb,Zn)_2(OH)VO_4$, and others.

It is a crystalline mass with a silver-white lustre, non-volatile, decomposing water at 100° C. It does not tarnish in air, burns in oxygen when heated, is insoluble in hydrochloric but soluble in nitric acid, in which solution it is blue.

Name its oxides.

Monoxide, V_2O;	Dioxide, V_2O_2;
Trioxide, V_2O_3;	Tetroxide, V_2O_4, hypovanadic acid;
Pentoxide, V_2O_5, vanadic oxide.	

Give the tests for vanadium compounds.

Vanadic and *chromic acids* are the only acids whose solutions are red. Vanadic acid becomes blue, while chromic acid becomes green by deoxidation.

What use has vanadium?

The salts are used in the manufacture of ink and as a dye-stuff, giving one of the best blacks, called *vanadium black*.

ANTIMONY (STIBIUM). Symbol **Sb.** Atomic weight 122.

How does antimony occur?

It is found as metallic antimony; as an oxide in the mineral valentinite, and chiefly as the sulphide, stibinite Sb_2S_3.

How is it prepared?

The ore is purified by fusion and afterwards decomposed by fusion with iron and potassium carbonate, which retain the sulphur.

What are the properties of antimony?

Bluish-white color, specific gravity 6.8, melting at 450°. It is volatile at a red heat. It does not oxidize in air at ordinary temperatures. Its vapor burns in air to dense white fumes of Sb_2O_3. It is soluble in hydrochloric acid with the evolution of hydrogen. Nitric acid oxidizes it to antimonic acid, an allotropic form, which is curiously explosive when heated or scratched.

What uses has antimony?

It is used:

(1) In medicine.

(2) In type-founding and casts. The addition of a little metallic antimony to lead causes the molten alloy to expand at the moment of solidifying, and take an exceedingly sharp impression of the mould; either lead or antimony alone shrinks when solidified. Toughness is imparted to the type-metal alloy by adding tin.

(3) For other alloys: *Britannia metal* is antimony and tin; *Pewter* is antimony, tin, and copper; *Babbit's antifriction metal* for bearings is antimony, lead, tin, and copper.

(4) Antimony, electrolytically deposited as a black powder by metallic zinc, is used for giving plaster-casts the appearance of steel. It is called *antimony black.*

(5) As a sulphide, Sb_2S_3, it is used in the composition of *blue* or *Bengal lights.*

Metallic zinc precipitates antimony from solution as a fine black powder.

What are the classes of antimony compounds?

It forms two classes of compounds, *antimonous* and *antimonic.*

What is antimonous hydride?

SbH_3, antimonous hydride, antimonetted hydrogen, or stibine, is prepared from zinc, sulphuric acid, and a solution of an antimony salt. It is a colorless gas, burning with a green flame and producing white fumes of Sb_2O_3. This gas is analogous to ammonia, NH_3; phosphine, PH_3, and arsine, AsH_3.

What are the chlorides of antimony?

They are the *trichloride,* $SbCl_3$, *antimonous chloride,* formerly called *butter of antimony,* which, when crystalline, was known as *powder of Algaroth,* and the pentachloride, $SbCl_5$. Antimony also forms *iodides, bromides,* and *fluorides.*

What is the trioxide of antimony?

Sb_2O_3, antimony trioxide or antimonous oxide, occurs as the minerals valentinite and senarmonite. It is dimorphous. When boiled with cream of tartar (acid potassium tartrate) it dissolves and crystallizes, and is called *tartar emetic.*

What is the tetroxide of antimony?

Sb_2O_4 is antimony tetroxide or antimonoso-antimonic oxide. The mineral cerrantite or antimony ochre may be regarded as a combination of Sb_2O_3 and Sb_2O_5.

How is the pentoxide prepared?

Sb_2O_5, pentoxide or antimonic oxide, is prepared by exposing metallic antimony to strong nitric acid. It forms an insoluble hydrate, which, by low heat, yields Sb_2O_5. The important salt is metantimoniate of potash, $K_2O.Sb_2O_5,7H_2O$. It is the only precipitant of sodium salts.

What acids do these oxides form?

The trioxide, Sb_2O_3, forms with water *orthoantimonous acid,* H_3SbO_3, and *meta-antimonous acid,* $HSbO_2$. With water the pentoxide, Sb_2O_5, forms *antimonic acid,* H_7SbO_3.

Give the sulphides of antimony.

Sb_2S_3, trisulphide or antimonous sulphide, occurs as the mineral stibnite, the principal ore of antimony. It may be prepared by fusing antimony and sulphur. It is a heavy gray mineral with metallic lustre.

Sb_2S_5, pentasulphide or antimonic sulphide, formerly called *sulphur aurantum*, is obtained by fusing together antimonous sulphide, sodium carbonate, slaked lime, and sulphur. It is an important ingredient of some firework mixtures. The artificial sulphide is orange-colored when produced in the laboratory by hydrogen sulphide in a solution of antimony. Heat changes it to the black form.

Mention the reagents which test the presence of antimony, and give the reactions.

(1) *Sulphuretted hydrogen* gives an orange or brick-red precipitate, soluble in ammonium sulphide, and reprecipitated by acids.

(2) *Caustic potash* in hydrochloric acid solutions gives a white precipitate soluble in an excess.

(3) *Ammonia* yields a white precipitate insoluble in an excess.

(4) *Potassium and sodium carbonates* yield a white precipitate soluble in an excess.

(5) SbH_3 burns and deposits rings of metallic antimony on porcelain held in the flame.

(6) *Zinc and iron* reduce antimonial salts to the metallic state.

(7) *Blowpipe-test:* An antimony salt on charcoal with *sodium carbonate* or *potassium cyanide* yields a brittle globule of antimony and thick white fumes of its oxide.

BISMUTH. Symbol **Bi**. Atomic weight 210.

How does bismuth occur?

Bismuth is found in veins, in the metallic state, in Saxony; also as an oxide, a sulphide, and a carbonate. It is prepared from the ore by melting it out from the gangue rock.

What are the properties of bismuth?

It is gray-white, brittle, having a specific gravity of 8.92, and is highly crystalline. It melts at 270° C., expands $\frac{1}{32}$ of its volume on solidifying, volatilizes at high temperatures, and is the most diamagnetic of all known bodies. It is little oxidized by air, but burns with a blue flame when strongly heated, and is soluble in nitric acid.

What are the bismuth chlorides?

Trichloride of bismuth, $BiCl_3$, bismuthous chloride, is formed by bismuth and chlorine gas, or bismuth in aqua regia, and is decomposed by water, yielding a white precipitate of oxychloride :—

$$BiCl_3 + H_2O = BiClO + 2HCl.$$

This precipitate is often formed from the salts by dilution with water.

BiOCl is used as a face powder (Blanche de Perle). It injures the skin.

Bichloride of bismuth, Bi_2Cl_4, is produced from the trichloride and metallic bismuth.

How is bismuth trioxide prepared?

The trioxide, Bi_2O_3, bismuthous oxide, is prepared by igniting the nitrate, hydrate, or carbonate. It is a straw-yellow powder, fusible at high temperatures, in which state it is a powerful flux for silica.

With water it forms the hydroxide, Bi_2O_3,H_2O or $BiHO_2$, soluble in acids, forming *bismuthous* salts, $BiCl_3$, $Bi(NO_3)_3$, $Bi_2(SO_4)_3$, etc. The normal nitrate, $Bi(NO_3)_3,5H_2O$, is decomposed by water, yielding insoluble *basic nitrate* or *subnitrate*, $Bi(OH)_2NO_3$. The basic nitrate is sometimes used as a cosmetic. It is, however, injurious to the skin. Medicinally, it is used for stomach and bowel diseases.

Give the tests for bismuth in compounds.

(1) *Water* gives a white precipitate to nitrate or chloride solutions.

(2) *Hydrogen sulphide* gives a black precipitate insoluble in ammonium sulphide.

(3) Blowpipe-test: On charcoal with bismuth flux (a mixture of KI aud S) it yields a beautiful red coating.

For what is bismuth used?

The metal is used in conjunction with antimony in the construction of thermo-electro piles, these two metals forming the opposite extremes of the thermo-electric series. Its alloys are remarkable for their low fusion point.

Rose's alloy, composed of 2 parts of bismuth, 1 part of lead, and 1 part of tin, melts at 93.7° C.

Wood's alloy, composed of 4 parts of bismuth, 2 parts of lead, 1 part of tin, and 1 part of cadmium, melts at 60.5° C.

They are used to make safety-plugs in boilers and for taking impressions from dies, etc.

TANTALUM. Symbol **Ta**. Atomic weight 182.

State the occurrence and properties of tantalum.

This very rare metal is of theoretical importance only. It occurs as the mineral tantalite, and is a black powder which when heated in air burns with a bright light into tantalic acid. It is insoluble in acids, excepting hydrofluoric.

Give the compounds of tantalum.

The principal compounds are $TaCl_5$, the chloride; TaF_5, the fluoride; Ta_2O_5, tantalic oxide, which forms tantalic acid and tantalates, and TaO_2, tantalous oxide.

NIOBIUM or COLUMBIUM. Symbol Nb. Atomic weight 94.

State the occurrence and character of niobium.

This very rare metal occurs in the rare minerals columbites and tantalites. It is a black powder oxidizing with incandescence when heated in the air and soluble in hot hydrofluoric acid and also in concentrated sulphuric acid.

What are the principal compounds of niobium?

$NbCl_5$, the chloride; Nb_2O_5, the oxide; $HNbO_3$, niobic acid (forms niobates), and $NbOF_3$ oxyfluoride, which unites with the fluorides of the more basic metals, forming salts isomorphous with the titanofluorides, stannofluorides, and tungstofluorides.

XII. METALS OF THE PLATINUM GROUP.

Name the metals of the platinum group.

Gold,
Platinum,
Palladium,
Rhodium,
Iridium,
Ruthenium,
Osmium.

What are their peculiarities?

These metals may be divided into three classes, according to their behavior with oxygen: (1) Gold and platinum do not combine directly with oxygen under any circumstances; (2) palladium, rhodium, and iridium oxidize when heated in air or oxygen, but their oxides decompose by strong ignition into oxygen and the metal; (3) ruthenium and osmium unite with oxygen to form volatile oxides which do not decompose even at the highest temperatures.

Gold (AURUM). Symbol Au. Atomic weight 196.2.

How is gold found?

This very widely diffused metal is almost universally found in small quantities in an uncombined state, the only exceptions being the tellurides, which also generally contain silver. It has been found in sea-water to the extent of about one grain of gold per ton of water.

Gold occurs to some extent in dust, grains, or nuggets, but the larger yield is from invisible particles diffused through veins of iron pyrites or quartz. The largest recorded Australian nugget weighed 2680 oz., while California produced one weighing 2340 oz.

Native gold is almost always alloyed with silver. The purest specimen from the Ural Mountains contained 98.9 per cent. of gold. Californian gold averages 88 per cent.; Australian gold averages 96 per cent.

Give the modes of obtaining gold.

Gold may be obtained from river sand by simple washing, or from auriferous earth by hydraulic mining. The earth, being displaced by water, and caused to flow through troughs containing mercury, dispenses with its gold, which forms an amalgam with the mercury, from which it is subsequently separated by distillation. Gold with quartz or veinstone is collected by mercury after crushing or milling the rock. The gold in combination with sulphides of arsenic, iron, and copper minerals is not attacked by mercury. The heavy material collected from the milling operation is called "concentrates," and is treated by the chlorine process, essentially as follows:—

The concentrates, mainly of iron pyrites with small amounts of arsenic and copper, are roasted to convert all the metals into oxides. After thoroughly roasting, chlorine gas is brought into contact, transforming the gold into a soluble chloride, which is extracted from the mass by leaching with water, and precipitated by ferrous sulphate:—

$$2AuCl_3 + 6FeSO_4 = 2Fe_2(SO_4)_3 + Fe_2Cl_6 + 2Au.$$

When these concentrates contain silver it is extracted from the leached material by solution in hyposulphite of sodium (see Silver).

Gold is separated from silver by a process called "parting. The crude bullion is melted with additional silver so that the alloy shall consist of three parts of silver to one of gold. This alloy is then melted and granulated and boiled with nitric or sulphuric acid, the silver going into solution and the gold remaining as a residue. It may also be separated electrolytically by making the gold and silver alloy the anode and a plate of pure silver the cathode, the solution into which these are immersed being nitric acid. By passing a current of electricity through this circuit the silver is dissolved from the alloy and deposited on the silver cathode, the gold remaining as an insoluble powder.

What are the properties of gold?

It is yellow and soft, the most malleable and ductile of all metals. It may be beaten into leaves $\frac{1}{282000}$ of an inch in thickness, or one grain may be drawn into wire 660 feet long. Gold melts at 1100° C., and is unaffected by air or water. It does not dissolve in any single acid, but it is soluble in aqua regia. With mercury it makes an amalgam. Light transmitted by gold-leaf assumes a greenish tinge. Gold is a trivalent element, forming two classes of compounds, *aurous* and *auric*.

How is gold alloyed?

Pure gold is too soft for practical uses, and is therefore hardened by alloying with copper or silver, the former yielding a ruddier and the latter a paler colored alloy. The coin standard for the United States is 900 fine, that is 900 parts of gold in 1000 parts of gold and alloy. Coin silver is alloyed in the same proportion. Jeweler's gold is generally less fine. Its character is indicated by a standard called *carat*, pure gold being 24 carats fine. One carat, therefore, equals $\frac{1}{24}$ part of gold.

Give the chlorides of gold and their uses?

AuCl, monochloride of gold or aurous chloride, is obtained by evaporation of the trichloride to dryness and exposing it to a heat of 227° C. till the excess of chlorine is expelled. The yellowish-white mass is decomposed slowly in cold and rapidly in hot water into metallic gold and the trichloride.

$AuCl_3$, gold trichloride or auric chloride, is the most important compound of gold. It is obtained by dissolving gold in aqua regia, and appears as a red crystalline mass, deliquescent, soluble in water, alcohol, and ether, sensitive to light, and forming double salts with a number of metallic chlorides, called *chloroaurates.* This chloride is used in "toning" photographs and also, when mixed with an excess of acid sodium or potassium carbonate, to gild small copper articles.

Mention the oxides of gold and their properties.

Au_2O, gold monoxide or aurous oxide, is a green powder partly soluble and easily decomposed into metallic gold and auric oxide.

Au_2O_3, trioxide of gold or auric oxide, is a chestnut-brown powder, reducible by heat or light, insoluble in nitric acid, but soluble in hydrochloric or hydrofluoric acid and in alkalies. When digested with ammonia it yields *fulminating gold*, $Au_2O_3,4NH_3,H_2O$. This trioxide forms *aurate* salts, as potassium aurate, $K_2O,Au_2O_3,6H_2O$ or $KAuO_2,3H_2O$, the solution of which may be used for electro-gilding.

A sodium aurous-thio-sulphate, $Na_3Au(S_2O_3)_2,2H_2O$, is used in "fixing" daguerrotype pictures.

The sulphides of gold are: AUROUS SULPHIDE, Au_2S, a black precipitate, and AURIC SULPHIDE, Au_2S_3, a yellow precipitate.

Give the tests for gold.

(1) *Ferrous sulphate* gives a brown precipitate fusible to a metallic bead.

(2) *Stannous chloride* produces a brownish-purple precipitate, called "purple of Cassius."

(3) *Oxalic acid* slowly reduces gold to its metallic state.

Mention some of the uses of gold.

Gold has an extensive use as a metal for coinage, jewelry, ornamentation, dentistry, gold-leaf gilding; also for imparting a red tint to glass (giving the purple of Cassius), for enamel-painting, and for lining platinum stills in the final concentration of sulphuric acid. Its salts are used for "fixing and toning" in photography. The double cyanide of gold and potassium is used in electroplating.

PLATINUM. Symbol **Pt.** Atomic weight 196.7.

How does platinum occur?

It occurs alloyed with palladium, rhodium, iridium, and iron, and as the very rare mineral sperrylite, an arsenide. The Ural Mountains yield the greater part of the world's supply. Platinum is prepared by a very complicated refining operation.

Give the properties of platinum.

It is a steel-white metal, of specific gravity 21.5. It is malleable and ductile, fusible at 1775° C., and insoluble in all acids except *aqua regia.* It may be superficially oxidized by fused potassium hydroxide. When in a finely divided state, "platinum black" condenses gases within its pores to a remarkable extent, one volume absorbing 800 volumes of oxygen. Platinum is a tetrad, forming two series of salts, *platinous* and *platinic.* Its compounds are many, complicated, and mainly of theoretical interest.

Give the chlorides of platinum.

Platinum dichloride or platinous chloride, $PtCl_2$, is prepared by the exposure of platinic chloride to heat.

The tetrachloride or platinic chloride, $PtCl_4$, is derived from a solution of platinum in *aqua regia.*

Both chlorides form double salts with metallic chlorides.

The *bromides* and *iodides* form analogous salts.

What are the oxides of platinum?

The monoxide or platinous oxide, PtO, and the dioxide or platinic oxide, PtO_2.

The SULPHIDES are PtS and PtS_2.

How are ammoniacal platinum compounds formed?

The chlorides, oxides, sulphates, etc., of platinum unite with two or more molecules of ammonia, forming compounds analogous to the mercur-ammonium compounds. With platinum and ammonium there are twelve distinct groups.

What are the tests for platinum compounds?

(1) *Hydrogen sulphide or ammonium sulphide* generally forms a brown precipitate, soluble in an excess of ammonium sulphide.

(2) *Zinc* precipitates metallic platinum.

(3) *The chloride of potassium or of ammonium, but not of sodium,* with a platinum compound yields a yellow granular precipitate.

For what is platinum used?

It is indispensable in the laboratory. The metal is used for making crucibles, dishes, capsules, wire, foil, etc.; for constructing stills for the final concentration of sulphuric acid; as the negative element in the Grove battery, and in construction of electrical apparatus. When used for stills, crucibles, etc., it is usually hardened with a little iridium. As a laboratory reagent the tetrachloride of platinum, $PtCl_4$, is used to separate potassium from sodium compounds (see test 3).

PALLADIUM. Symbol **Pd.** Atomic weight 106.2.

How is palladium obtained?

This rare metal, of little importance, is found alloyed with platinum and with gold. In color and appearance it closely resembles platinum, also in being very malleable and ductile, although more oxidizable. It oxidizes at a red heat in air, and is soluble in nitric and hydrochloric acids.

What are its compounds?

Palladium forms two classes of compounds, *palladious* and *palladic*.

The *Chlorides* are $PdCl_2$ and $PdCl_4$; the *Oxides*, PdO and PdO_2; the *Sulphide*, PdS.

What uses has palladium?

On account of its constancy in air and its silver-white color, which is not affected by exposure to sulphuretted hydrogen, it is used for graduated surfaces for astronomical instruments, for plating silver goods, and in dentistry as an amalgam.

RHODIUM. Symbol **Rh.** Atomic weight 104.1.

How does rhodium occur?

This extremely rare metal is found alloyed with platinum. It is brittle, oxidizable, insoluble in acid, and less fusible and weldable than platinum.

What are its compounds?

Its chloride, $RhCl_3$, forms double salts with potassium and ammonium compounds. Its oxides are the monoxide, RhO; sesquioxide, Rh_2O_3; dioxide, RhO_2. Its sulphate, $Rh_2(SO_4)_3,12H_2O$, forms compounds with ammonia.

What use has rhodium?

(1) It is used for the thermo-electric pyrometer.

(2) Alloyed with steel in equal parts it gives a metallic surface which does not tarnish in air.

IRIDIUM. Symbol **Ir.** Atomic weight 196.7.

Where does iridium occur?

It is found in gold washings, and with platinum and osmium in an alloy called *iridosmine.* It is very infusible, and insoluble in acids.

What are its compounds?

They are of three forms: hypoiridious, iridious, and iridic. The dichloride, $IrCl_2$, is not obtained in a separate state. The other chlorides are the trichloride, $IrCl_3$ or Ir_2Cl_6, iridious chloride, and the tetrachloride, $IrCl_4$, or iridic chloride, which forms double salts with the chloride of potassium, sodium, and ammonium. The oxides are the monoxide, IrO, hypoiridious oxide; sesquioxide, Ir_2O_3, iridious oxide; dioxide, IrO_2, iridic oxide. The sulphides are IrS, Ir_2S_3, IrS_2. Its ammoniacal compounds are analogous to the same compounds of the platinum series.

What are the uses of iridium?

Iridosmine is harder than steel, and is used for tipping gold pens. It can be electrolytically deposited as plate.

RUTHENIUM. Symbol **Ru.** Atomic weight 103.5.

Give the properties and compounds of ruthenium.

It occurs in platinum and iridosmine. It is the most refractory of all elements except osmium, and more easily oxidized than platinum or silver, but scarcely attacked by *aqua regia.*

Chlorides, $RuCl_2$, $RuCl_3$, $RuCl_4$;
Oxides, RuO, Ru_2O_3, RuO_2, RuO_3, Ru_2O_7, RuO_4
Sulphides, RuS_2, Ru_2S_3.
It forms compounds with ammonia.

OSMIUM. Symbol **Os.** Atomic weight 198.6.

How is osmium found?

It is found associated with gold and platinum compounds. Its properties vary according to the manner in which it is prepared, but it is a hard, heavy, refractory metal, which, in a finely divided state, burns in air to a tetroxide.

Give formulæ for its chlorides, oxides, and sulphides.

Chlorides, $OsCl_2$, $OsCl_3$, $OsCl_4$;
Oxides, OsO, Os_2O_3, OsO_2, OsO_3, OsO_4;
Sulphides, OsS, Os_2S_3, OsS_2, OsS_3, OsS_4.
It forms compounds with ammonia.

ORGANIC CHEMISTRY.

GENERAL CONSIDERATIONS.

Explain the derivation and meaning of the term organic chemistry.

The chemistry of the compounds found in plants and animals was originally called organic chemistry, and this designation was introduced at the time of Lavoisier (about 1750), who first recognized the true composition of these substances. He showed that when they undergo combustion CO_2 and H_2O are always formed, and that their component elements are carbon, hydrogen, and oxygen, and sometimes nitrogen, with one or two others.

Soon after this it became evident that products of the animal and vegetable kingdoms possess a composition different from the mineral.

For a long time all attempts to *produce* these organic compounds *from* their elements failed, and the opinion therefore existed that they were different from mineral substances and could only be formed by a peculiar power, inherent in plants and animals, called the "vital force."

In the year 1828, Wöhler succeeded in producing urea from the mineral salt ammonium cyanate, and, following this, other syntheses soon showed that organic substances could be made from their elements without the aid of the "vital force."

At present we know that the peculiarities of organic compounds are dependent solely on the nature of their essential constituent, *carbon*, and that all substances belonging to plants and animals can be prepared from their elements.

Organic chemistry is therefore the chemistry of the carbon compounds, and it is separated from mineral chemistry on account of the vast number of its derivatives and their special properties as a class.

It is well to note the difference between *organic* and *organized* bodies.

Certain carbon compounds ossess the power to assume, in the living organism, an "*organized*" or "*cellular*" structure, but the causes and conditions of this power have not yet been discovered.

Give the general characteristics of organic bodies.

Organic bodies are in general distinguished by the facility with which they decompose under the influence of heat and chemical reagents; the more complex the structure, the more readily are they decomposed or split up into simple groups.

They also easily burn, ferment, decay, and putrefy. They are generally composed of few elements, principally carbon, hydrogen, and oxygen, and sometimes nitrogen; also sulphur and phosphorus. *Artificial* compounds of these elements with most of the *metals* have also been prepared.

SYNTHESIS.

Give a few examples of the syntheses of organic compounds from their elements.

(*a*) Acetylene, C_2H_2, can be prepared by passing electric sparks, between carbon poles, through hydrogen gas.

(*b*) Potassium formate, HCOOK, by passing carbon monoxide over potassium hydroxide :—

$$CO + KOH = HCOOK.$$

(*c*) Ethyl alcohol (ordinary alcohol) an be made by first making *acetylene*, as above, and then converting this into *ethylene* by the addition of hydrogen ; thus :—

$$C_2H_2 + H_2 = C_2H_4.$$

The ethylene is now dissolved in sulphuric acid, forming ethyl sulphuric acid—

$$C_2H_4 + H_2SO_4 = C_2H_5HSO_4 ;$$

and this boiled with water gives ethly alcohol and sulphuric acid—

$$C_2H_5HSO_4 + H_2O = C_2H_5OH + H_2SO_4.$$

ANALYSIS.

What are the two kinds of analysis used in organic chemistry?

In organic chemistry there are two kinds of analysis to be considered :—

(1) The separation of the constituents of a mixture into known substances, viz.: the separation of *wine* into *alcohol*, *sugar*, *salts*, etc. This is called *proximate analysis.*

(2) The estimation of each of the elements which compose an organic body, as the determination of *carbon*, *hydrogen*, and *oxygen* in *alcohol* (C_2H_6O). This is called *ultimate analysis.*

(1) *Proximate analysis* is treated in books specially written on the subject, and will not be considered here.

(2) In *ultimate analysis* the carbon and hydrogen are determined by "*direct weighing*" and the oxygen by "*difference.*"

How are carbon and hydrogen determined?

To determine carbon and hydrogen in a substance, if it is a solid, it is mixed with copper oxide, CuO, and burned in a glass tube closed at one end. The products of combustion—water, H_2O, and carbon dioxide, CO_2—are caught in suitable apparatus at the open end, and from their weights the percentage of hydrogen and carbon in the substance can be determined.

The water is caught in a chloride of calcium tube and the carbon dioxide in a potash bulb.

From the percentage composition of the substance the formula may be calculated, as will be shown further on.

When other elements are present the operation must be slightly modified, as it is necessary to test for other elements like nitrogen, the halogens, sulphur, etc., and to make provision for them, as they interfere with the estimation of carbon and hydrogen.

What is the method of simply testing the presence of carbon and hydrogen in a substance?

When a compound of C, H, and O, as sugar, is heated slowly to redness in a hard glass tube, drops of water will collect "on the cooler portion of the tube" and a mass of charcoal or carbon will remain behind; the water shows the presence of hydrogen and oxygen. The latter is generally determined by "difference."

What is a test for nitrogen?

Nitrogen, in the form of albumenoids, is detected by fusing the substance with caustic potash, dissolving the fusion in water, filtering, adding sulphate of iron and perchloride of iron, then boiling and adding hydrochloric acid. A precipitate of Prussian blue indicates the presence of nitrogen.

How is nitrogen in albumenoids determined?

Nitrogen is determined by heating the substance with caustic alkalies, catching the evolved ammonia in hydrochloric acid, and determining the ammonium chloride, from which the nitrogen may be calculated by known methods.

Describe the absolute methods of determining nitrogen.

The substance is mixed with oxide of copper and heated in a tube closed at one end; the oxides of nitrogen formed are led over metallic copper heated to redness, by which they are reduced to nitrogen; the latter is caught in a graduated cylinder and its volume read off, from which the quantity of nitrogen in the substance can be calculated.

What are the tests for sulphur?

The substance is fused with carbonate and nitrate of sodium, the fusion taken up with water, filtered, acidified with hydrochloric acid, and barium chloride is added. A white precipitate of barium sulphate = S. Or, if very small quantities of sulphur are to be detected, a few drops of a solution of nitroprusside of sodium are added to the fused mass, which is dissolved in water. A blue color = S.

How is sulphur estimated?

The substance is treated as above, and the barium sulphate weighed, from which the per cent. of sulphur may be calculated.

Mention a test for halogens.

The substance is mixed with oxide of copper and heated on a platinum wire in the blowpipe flame. If halogens are present, the flame will be colored green.

How are the halogens determined?

The substance is fused, as for the estimation of sulphur, the watery solution of the fusion acidified with nitric acid, and silver nitrate added. From the weight of the haloid silver-salt the quantity of halogen can be calculated.

Give a test for phosphorus.

Phosphorus may be tested for in the same way as sulphur; that is, fused, the fusion taken up with water, and the phosphates precipitated by "magnesia mixture" as a white crystalline precipitate.

Give an example of an ultimate analysis for C and H.

By weighing the potash bulb and the calcium chloride tube before and after the combustion, the quantity of carbon dioxide and water can be determined for a given weight of substance, and the per cent. of each element calculated from these weights, thus:—

Take sugar for example, $C_{12}H_{22}O_{11}$.

Weight of potash bulb (before) . . .	773.82 grs.
" " " (after) . . .	781.13 "
" CO_2	7.31 "
Weight of calcium chloride tube (before) . .	223.30 grs.
" " " " (after) . .	226.05 "
" H_2O	2.75 "

Carbonic acid gas contains 12 parts of carbon in 44 parts of the gas, and there are 2 parts of hydrogen in 18 parts of water.

Therefore in 7.31 parts of CO_2 there are $7.31 \times \frac{12}{44} = 1.994$ parts of carbon; and in 2.75 parts of water there are $2.75 \times \frac{2}{18} = 3.056$ parts of hydrogen, or in percentages:—

Carbon	41.98
Hydrogen	6.43
Oxygen	51.59 by difference.

By dividing the percentage of each element by its atomic weight we obtain the relative proportions of the elements, thus:—

$$\frac{41.98}{12} = 3.50 \text{ carbon};$$

$$\frac{6.43}{1} = 6.43 \text{ hydrogen};$$

$$\frac{51.59}{16} = 3.22 \text{ oxygen};$$

now dividing these by the smallest figure (*i. e.*, 3.22), we obtain—

$$\frac{3.50}{3.22} = 1.087 \text{ or C};$$

$$\frac{6.43}{3.22} = 2.0 \quad \text{or } H_2;$$

$$\frac{3.22}{3.22} = 1.0 \quad \text{or O}.$$

This gives us $C_1H_2O_1$, which is the simplest expression of the number of atoms in the molecule, and it is called the *empirical* formula. In this way we obtain the empirical formula from the analysis. The *molecular* or true formula must be obtained by other means, generally by determining the specific gravity of the substance in the form of gas, or, as it is called, *vapor density.*

Describe the method of determining vapor density.

This determination is necessary in order to find the molecular weight or formula of a substance, and is only applicable to substances that boil without decomposition.

The principle of the determination is the same as with solids or liquids, *i. e.*, the comparison of the weights of equal volumes of the substance, in the gaseous form. The standard air is used in most cases, especially for liquids, and hydrogen for gases. The most important methods are those of Dumas, Hofmann, and Victor Meyer. For the details of these methods larger works should be consulted.

When the substance is not volatile or does not boil without decomposition, other methods must be used to determine its molecular weight. The vapor density multiplied by two gives the molecular weight.

What are these other methods?

The first (called Raoult's method) depends upon the fact that the freezing-point of a liquid is lowered a certain number of degrees when a substance is dissolved in that liquid.

The second (called Beckmann's method) depends upon the fact that the boiling-point of a liquid is raised a certain number of degrees when a substance is dissolved in it.

The apparatus used and the details of the operations can be found in larger works on Chemistry.

FORMULÆ.

Mention the different kinds of formulæ.

They are empirical, molecular, rational, and graphic or constitutional.

Define empirical formulæ, and give examples.

The empirical formula shows the relative number or the simplest ratio of the atoms in the molecule. Thus :—

	Molecular formula.	Empirical formula.
Glucose	$C_6H_{12}O_6$	CH_2O ;
Acetic acid	$C_2H_4O_2$	CH_2O ;
Ethylene	C_2H_4	CH_2.

Define molecular formulæ, and give examples.

Molecular formulæ show the exact number of atoms in the molecule, and are obtained from the vapor density, etc. Examples may be seen in the last question.

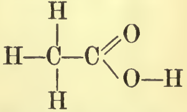
What are rational formulæ?

Rational formulæ separate the molecule into groups, indicating the class of compounds to which the substance belongs. Thus :—

	Molecular formula.	Rational formula.
Alcohol	C_2H_6O	C_2H_5OH ;
Acetic acid	$C_2H_4O_2$	CH_3COOH ;
Aldehyde	C_2H_4O	CH_3COH.

What are graphic formulæ?

Graphic formulæ endeavor to show the way in which the atoms are joined and arranged within the molecule. Thus :—

		Graphic formula.
Acetic acid	$C_2H_4O_2$	

The atoms are connected by lines called bonds, which also indicate the atomicity of the elements.

What are "types"?

In order to show how compounds decompose, and to aid in recognizing them, their formulæ are written like the formulæ of some well-known compounds, called "types." The types and their structure, with some examples, are given in the following table :—

Hydrogen	$\begin{matrix}H\\H\end{matrix}\Big\rangle$	Hydrogen chloride	$\begin{matrix}H\\Cl\end{matrix}\Big\rangle$	Water	$\begin{matrix}H\\H\end{matrix}\Big\rangle O$	Ammonia	$\begin{matrix}H\\H\\H\end{matrix}\Big\rangle N$	Marsh-gas	$\begin{matrix}H\\H\\H\\H\end{matrix}\Big\rangle C$
Ethyl hydride	$\begin{matrix}C_2H_5\\H\end{matrix}\Big\rangle$	Ethyl chloride	$\begin{matrix}C_2H_5\\Cl\end{matrix}\Big\rangle$	Ethyl alcohol	$\begin{matrix}C_2H_5\\H\end{matrix}\Big\rangle O$	Ethylamine	$\begin{matrix}C_2H_5\\H\\H\end{matrix}\Big\rangle N$	Ethyl methane	$\begin{matrix}C_2H_5\\H\\H\\H\end{matrix}\Big\rangle C$
Diethyl	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\Big\rangle$	Acetyl chloride	$\begin{matrix}C_2H_3O\\Cl\end{matrix}\Big\rangle$	Ethyl ether	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\Big\rangle O$	Diethylamine	$\begin{matrix}C_2H_5\\C_2H_5\\H\end{matrix}\Big\rangle N$	Chloroform	$\begin{matrix}H\\Cl\\Cl\\Cl\end{matrix}\Big\rangle C$
Acetyl hydride	$\begin{matrix}C_2H_3O\\H\end{matrix}\Big\rangle$	Benzoyl chloride	$\begin{matrix}C_7H_5O\\Cl\end{matrix}\Big\rangle$	Acetic acid	$\begin{matrix}C_2H_3O\\H\end{matrix}\Big\rangle O$	Trimethylamine	$\begin{matrix}CH_3\\CH_3\\CH_3\end{matrix}\Big\rangle N$	Alcohol	$\begin{matrix}CH_3\\H\\H\\HO\end{matrix}\Big\rangle C$
Acetyl methyl	$\begin{matrix}C_2H_3O\\CH_3\end{matrix}\Big\rangle$			Acetic anhydride	$\begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}\Big\rangle O$	Acetamide	$\begin{matrix}C_2H_3O\\H\\H\end{matrix}\Big\rangle N$	Formic acid	$\begin{matrix}H\\O=\\HO\end{matrix}\Big\rangle C$
Cyanogen hydride	$\begin{matrix}NC\\H\end{matrix}\Big\rangle$	Cyanogen chloride	$\begin{matrix}NC\\Cl\end{matrix}\Big\rangle$	Cyanic acid	$\begin{matrix}NC\\H\end{matrix}\Big\rangle O$	Isocyanic acid	$\begin{matrix}OC=\\H\end{matrix}\Big\rangle N$	Hydrocyanic acid	$\begin{matrix}N\equiv\\H\end{matrix}\Big\rangle C$

ISOMERISM.

Define isomerism.

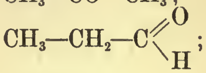
Two compounds are said to be isomeric when they have the same percentage-composition, but show different properties.

They are divided into two classes: (*a*) those that have the same molecular weight are called *metameric;* (*b*) those that have a different molecular weight are called *polymeric.*

What are metameric bodies?

(*a*) Bodies which have the same percentage-composition and molecular weight, but show different decompositions under similar conditions, are called metameric.

Thus three bodies correspond to the formula C_3H_6O :—

Acetone	$CH_3—CO—CH_3$;
Propionic aldehyde . . .	 $CH_3—CH_2—C\begin{array}{l}{/\!\!/}O\\ {\backslash}H\end{array}$;
Allyl alcohol	C_3H_5OH.

What are polymeric bodies?

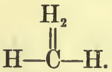
(*b*) Bodies which have the same percentage-composition, but different molecular weights, are called polymeric. Thus:—

Ethylene	C_2H_4 ;
Butylene	C_4H_8.

CLASSES OF ORGANIC COMPOUNDS.

Give a classification of organic compounds, with the name and graphic formula of each.

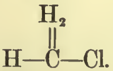
(1) Hydrocarbon,



$$H—\overset{\overset{\displaystyle H_2}{\|}}{C}—H.$$

Methane.

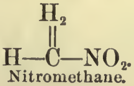
(2) Haloid ether,



$$H—\overset{\overset{\displaystyle H_2}{\|}}{C}—Cl.$$

Methyl chloride.

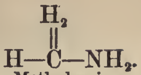
(3) Nitroparaffine,



$$H—\overset{\overset{\displaystyle H_2}{\|}}{C}—NO_2.$$

Nitromethane.

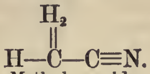
4) Amidoparaffine,



$$H-\overset{\overset{H_2}{\|}}{C}-NH_2.$$

Methylamine.

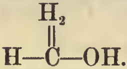
(5) Nitryl,



$$H-\overset{\overset{H_2}{\|}}{C}-C\equiv N.$$

Methyl cyanide.

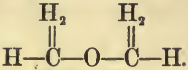
(6) Alcohol,



$$H-\overset{\overset{H_2}{\|}}{C}-OH.$$

Methyl alcohol.

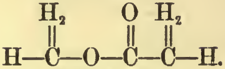
(7) Simple ether,



$$H-\overset{\overset{H_2}{\|}}{C}-O-\overset{\overset{H_2}{\|}}{C}-H.$$

Methyl ether.

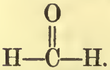
(8) Ester,



$$H-\overset{\overset{H_2}{\|}}{C}-O-\overset{\overset{O}{\|}}{C}-\overset{\overset{H_2}{\|}}{C}-H.$$

Methyl acetate.

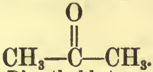
(9) Aldehyde,



$$H-\overset{\overset{O}{\|}}{C}-H.$$

Formic aldehyde.

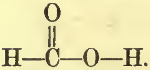
(10) Ketone,



$$CH_3-\overset{\overset{O}{\|}}{C}-CH_3.$$

Dimethyl ketone.

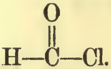
(11) Acid,



$$H-\overset{\overset{O}{\|}}{C}-O-H.$$

Formic acid.

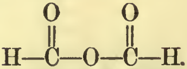
(12) Acid haloid,



$$H-\overset{\overset{O}{\|}}{C}-Cl.$$

Formyl chloride.

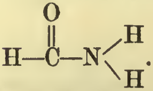
(13) Acid anhydride,



$$H-\overset{\overset{O}{\|}}{C}-O-\overset{\overset{O}{\|}}{C}-H.$$

Formic anhydride.

(14) Amide,



$$H-\overset{\overset{O}{\|}}{C}-N\begin{matrix}\diagup H\\ \diagdown H\end{matrix}.$$

Formamide.

HYDROCARBONS.

The various compounds of carbon and hydrogen are called hydrocarbons. They are all derived from methane or marsh-gas, CH_4. One series is formed by replacing a hydrogen atom in CH_4 by $(CH_3)'$, called methyl, thus giving $CH_3—CH_3$, ethane; and so on, $CH_3—CH_2—CH_3$, propane, etc. If two hydrogens are replaced by $(CH_2)''$, an unsaturated series of compounds is formed, called olefines: $(CH_2{=}CH_2)$, ethylene. If three are replaced by the radical $(CH)'''$, then acetylenes are formed: $CH{\equiv}CH$, acetylene. The other unsaturated hydrocarbons are given below.

Give the different series of hydrocarbons.

Methane or marsh-gas (C_nH_{2n+2}) . .	CH_4	gases.
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Quintane	C_5H_{12},	liquid.
Pentatriacontane (the highest) . .	$C_{35}H_{72}$,	solid.

The other series are olefines, C_nH_{2n} :—

Ethylene, C_2H_4; Propylene, C_3H_6; Butylene, C_4H_8, etc.

The next are acetylenes, C_nH_{2n-2} :—

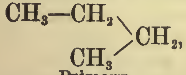
Acetylene, C_2H_2; Allylene, C_3H_4; Crotonylene, C_4H_6.

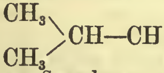
Mention some other unsaturated hydrocarbons.

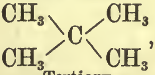
Valylene, $(C_nH_{2n-4})C_5H_6$;
Dipropargyl, $(C_nH_{2n-6})C_6H_6$; this compound is isomeric with the aromatic compound benzene, C_6H_6.

What are meant by primary, secondary, and tertiary compounds?

When two radicals are joined to the radical $(CH_2)''$ the compound is said to have a primary structure; if three radicals are joined to $(CH)'''$, it is called secondary, and if all the hydrogens in methane, or (CH_4), are replaced by radicals, the compound is called tertiary :—


Primary.


Secondary.

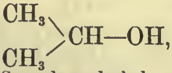

, etc.

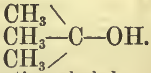
Tertiary.

These names are not only applied to "hydrocarbons," but also to other derivatives, as alcohols :—

$CH_3—CH_2—CH_2—OH—$,

Primary alcohol.


Secondary alcohol.


Tertiary alcohol.

THE HYDROCARBONS IN DETAIL.

Give the occurrence and formation of the paraffines C_nH_{2n+2}.

Many of the paraffines occur ready formed in American petroleum and other mineral oils of similar origin, namely :—

Natural gas, coal oil, asphalt oil, and other natural residues of decomposition of vegetation like boghead, cannel coal, and Burmese tar.

Describe the method of purifying petroleum.

It is first treated with concentrated sulphuric acid, which dissolves the unsaturated hydrocarbons and destroys other organic substances. The acid is then drawn off (called sludge acid or "sludge") and the oil treated with caustic soda, washed, and distilled.

Give the products and the average yield of a sample of petroleum.

Gasoline	1.25	per cent.
Refined naphtha	10.0	"
Benzene	4.0	"
Kerosene	55.0	"
Lubricating oils	17.75	"
Paraffine	2.0	"
Gas, carbon	10.0	"
	100.0	

For burning purposes :—

Crude naphtha	20.0	per cent.
Burning oil	66.0	"
Gas, carbon, etc.	14.0	"
	100.0	

Paraffines are also formed by the action of zinc and water on the haloid ethers :—

$$2C_2H_5I + 2Zn + 2H_2O = 2C_2H_6 + Zn(OH)_2 + ZnI_2.$$

What are the properties of paraffines?

The paraffines, depending on their carbon-contents, are either solids, liquids, or gases. They are saturated hydrocarbons, *i. e.*, cannot form additional products. Chlorine and bromine in sunlight give substitution-products. They are not easily acted upon by reagents. The lower members are not attacked by nitric acid, but the higher ones form nitro compounds.

What are cyanides or nitryls?

They are paraffines in which one or more hydrogen atoms have been replaced by cyanogen, CN or Cy : C_2H_5CN from C_2H_6.

The most important member of this group is *hydrogen cyanide*, or hydrocyanic acid (prussic acid), HCN or HCy, which can be obtained by the direct combination of its elements.

How is hydrocyanic acid prepared?

It is obtained by heating potassium ferrocyanide with dilute sulphuric acid:—

$$2K_4Fe(CN)_6 + 3H_2SO_4 = 6HCN + K_2Fe_2(CN)_6 + 3K_2SO_4.$$

What are its properties?

It is a thin, colorless, volatile liquid. Its odor resembles that of peach blossoms. It is a very feeble acid and easily decomposes. The anhydrous acid is probably the most poisonous substance known. Even the dilute solution used in pharmacy (2 per cent.) is very energetic in its action.

Give the names and the formulæ of some of the important derivatives of cyanogen.

Potassium cyanide	KCN;
Potassium ferrocyanide	$K_4Fe(CN)_6$;
Sodium nitroprusside (used as a test for sulphur)	$Na_2NOFe(CN)_6$;
Allyl isosulphocyanide (oil of mustard)	C_3H_5NCS;
Nitroaceto-nitryl (called fulminic acid)	CH_2NO_2CN.

The salts of this acid are explosive. The silver salt ($Ag_2C_2N_2O_2$) is one of the most explosive substances known.

What are haloid ethers?

They are hydrocarbons in which one or more hydrogen atoms have been replaced by halogen atoms, thus:—

CH_3Cl, methyl chloride; $C_2H_4Br_2$, ethylene bromide; $C_3H_5Cl_3$, propenyl chloride, etc.

They may be monatomic, diatomic, or polyatomic, and saturated or unsaturated.

How are they prepared?

(1) By the action of halogens on hydrocarbons in sunlight.

(2) By the addition of halogens or halogen acids to unsaturated hydrocarbons:—

$$\begin{aligned} C_2H_4 + Cl_2 &= C_2H_4Cl_2; \\ C_2H_2 + 2Cl_2 &= C_2H_2Cl_4; \\ C_2H_4 + HBr &= C_2H_5Br. \end{aligned}$$

What are their properties?

They are mostly colorless ethereal-smelling liquids, insoluble in water. Chlorides and bromides burn with a green-bordered flame. With caustic alkalies they give unsaturated hydrocarbons; with moist silver oxide they yield alcohols.

Mention the principal haloid ethers, with the preparation and properties of each.

Monatomic: methyl chloride, CH_3Cl; prepared by the action of chlorine on marsh-gas in sunlight:—

$$CH_4 + Cl_2 = CH_3Cl + HCl.$$

It is used for making "coal-tar" colors.

Methyl iodide, CH_3I; prepared by the action of phosphorus and iodine on methyl alcohol:—

$$3CH_3OH + P + 3I = 3CH_3I + H_3PO_3.$$

It is used for the same purpose as methyl chloride.

Diatomic: ethylene chloride, called "Dutch liquid," $C_2H_4Cl_2$; prepared by the union of chlorine with ethylene:—

$$C_2H_4 + Cl_2 = C_2H_4Cl_2.$$

These ethers are heavy oily liquids that boil without decomposition. They yield unsaturated hydrocarbons when treated with potash:—

$$C_2H_4Cl_2 + 2KOH = C_2H_2 + 2KCl + 2H_2O.$$

What are the most important triatomic haloid ethers?

Chloroform and iodoform.

Give a short account of chloroform.

Chloroform, $CHCl_3$ (methenyl chloride).

The discovery of chloroform is generally ascribed to Liebig, 1831, but by some writers to Guthrie.

It is prepared by the action of bleaching-powder on alcohol:—

$$2C_2H_5OH + 5Ca(ClO)_2 = 2CHCl_3 + 2CaCO_3 + 2CaCl_2 + Ca(OH)_2 + 4H_2O.$$

This mixture is subjected to distillation, and water and chloroform are the result. The latter, on account of its gravity, sinks to the bottom and can be drawn off and rectified.

What are its properties?

It is a thin colorless liquid of an agreeable odor and sweetish taste. It is heavier than water, boils at 61° C., and does not burn readily. Heated with potash it is decomposed into chloride and formate of potassium and water:—

$$CHCl_3 + 4KOH = 3KCl + HCO_2K + 2H_2O.$$

It is used as an anæsthetic.

Give a similar account of iodoform.

It is produced by the action of iodine and potash on ethyl alcohol.

It is a yellow solid, nearly insoluble in water, but dissolves in alcohol and ether. It possesses a characteristic smell. It is used in surgery as an antiseptic.

Mention a few other haloid ethers.

Tetrachlormethane (carbon tetrachloride) CCl_4;

Carbon trichloride C_2Cl_6; Carbon monochloride C_2Cl_2.

Ethyl chloride, C_2H_5Cl, is used as an anæsthetic in medicine and for a freezing-mixture. Bromine and iodine compounds are also known.

What are nitroparaffines?

They are hydrocarbons in which one or more hydrogen atoms have been replaced by nitryl (NO_2), thus :—

$$C_2H_5NO_2 \text{ from } C_2H_6.$$

How are they prepared?

By the action of silver nitrite on haloid ethers :—

$$C_2H_5I + AgNO_2 = C_2H_5NO_2 + AgI.$$

What are their properties?

They are agreeable smelling liquids, which explode if heated quickly. They are not decomposed by caustic alkalies. The mon derivatives by reduction give amines.

Mention some of the nitro compounds.

Nitroethane, $CH_3 - CH_2 - NO_2$;
Trinitromethane, $CH(NO_2)$, called nitroform;
Tetranitromethane, $C(NO_2)_4$;
Chlorpicrin, $CCl_3(NO_2)$, called nitrochloroform.

What are amines or amidoparaffines?

They are hydrocarbons in which one or more hydrogen atoms have been replaced by amidogen :—

$$CH_3NH_2 \text{ (methylamine) from } CH_4.$$

What are alcohols?

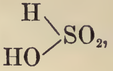
Alcohols are hydrocarbons in which one or more hydrogen atoms have been replaced by hydroxyl. They are called mono, di, tri, or tetratomic, according to the number of hydroxyls they contain. The hydrogen of the hydroxyl can be replaced by metals, forming alcoholates, or by alcohol radicals (alkyls), giving ethers. If the hydrogen atom is replaced by acid radicals, compound ethers (esters) are formed.

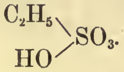
How are the esters formed?

They are formed by boiling acids or acid chlorides with alcohol:—

$$H_2SO_4 + C_2H_5OH = HC_2H_5SO_4 + H_2O;$$
$$C_2H_4O_2 + C_2H_5OH = C_2H_5C_2H_3O_2 + H_2O.$$

What are sulphonic acids?

The esters of unsymmetrical sulphurous acid,  are called sulphonic acids:—



The fatty sulphonic acids are not important, and will not be considered. Other esters are ethyl nitrate, $C_2H_5NO_3$, and ethyl nitrite, $C_2H_5NO_2$. They are considered further on.

How are monatomic alcohols $C_nH_{2n+1}OH$ formed?

(1) By the action of moist silver oxide on the haloid ethers:—

$$2CH_3I + Ag_2OH_2O = 2CH_3OH + 2AgI.$$

(2) By synthetic processes from their elements.
(3) By the fermentation of sugars:—

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2.$$

Give a table of the most important alcohols and their source.

Methyl	alcohol,	CH_3OH,	by distilling wood;
Ethyl	"	C_2H_5OH,	by the fermentation of sugar;
Propyl	"	C_3H_7OH,	from fusel oil in potatoes;
Butyl	"	C_4H_9OH,	" " " "
Amyl	"	$C_5H_{11}OH$	" " " "

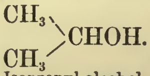
the others are caproic, $C_6H_{13}OH$, etc., and continue as far as $C_{30}H_{61}OH$, melissyl alcohol.

How are the isomeric alcohols classified?

The possible isomeric alcohols from any formula may be derived from the corresponding hydrocarbon. There is only one possible structure for the first and second members of the series, but two are possible with the third:—

$CH_3—CH_2—CH_2OH$, or

Propyl alcohol.



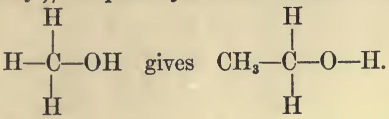
Isopropyl alcohol.

The number increases with the number of carbon atoms. Thus :—

Butyl alcohol,	C_4H_9OH,	four isomers ;
Amyl "	$C_5H_{11}OH$,	eight isomers ;
Caproyl "	$C_6H_{13}OH$,	seventeen isomers.

What is Kolbe's method of formulating alcohols ?

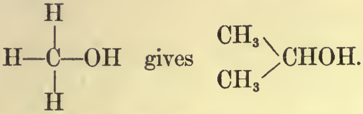
They are considered as derivatives of methyl alcohol or carbinol, CH_3OH. By replacing one hydrogen in carbinol by a hydrocarbon or alcohol-radical (alkyl), the primary alcohols result. Thus :—



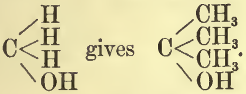
$$H-\underset{H}{\overset{H}{C}}-OH \quad \text{gives} \quad CH_3-\underset{H}{\overset{H}{C}}-O-H.$$

If the replacing group is normal, the alcohol will be normal.

If two hydrogens in carbinol are replaced by radicals or alkyls, secondary alcohols result :—



When all three hydrogens are replaced by alkyls, tertiary alcohols result :—



How are primary, secondary, and tertiary alcohols distinguished ?

Primary contain the group $(CH_2OH)'$, and give aldehydes and acids of the same carbon-contents on oxidation. Secondary contain the group $(CHOH)''$, and give ketones by oxidation. Tertiary contain the group $(COH)'''$, and yield acids of lower carbon-contents by the same treatment.

How is methyl alcohol or carbinol obtained ?

It can be prepared by any of the methods given for alcohols ; but it is prepared on a large scale from crude wood-vinegar obtained by the destructive distillation of wood. The distillate contains about 1 per cent. of alcohol. It is treated with lime and redistilled, and a weak alcohol obtained which is concentrated by repeated distillation with lime.

What are the properties of methyl alcohol ?

Pure methyl alcohol is a light, colorless liquid, boiling at 66° C. It is similar to ethyl alcohol in most of its properties, and it is often used for it in the arts, because it is cheaper. A mixture of crude wood-spirit (10 per cent.) and ethyl alcohol is sold under the name of methylated spirit, and as it cannot be used for making liquors, it is sold cheaper than "alcohol." It is used very largely abroad.

It forms esters with the acids by boiling or other reactions already given.

Examples:—

Methyl chloride, CH_3Cl; Methyl nitrate, CH_3NO_3;
Methyl acetate, $CH_3C_2H_3O_2$.

How is ethyl alcohol (C_2H_5OH) prepared?

(1) It can be obtained from its elements (see Introduction).

(2) From the haloid ethers (see under Formations of Alcohols).

(3) The method used almost entirely for its production is by the fermentation of sugar:—

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

The alcohol is then obtained and purified by distillation.

What are its properties?

It is a colorless, limpid liquid of a pungent and agreeable odor and taste. Its specific gravity is 0.7938 at 15.5° C. It is very inflammable, burning with a smokeless flame giving intense heat. It mixes with water in all proportions, is a great solvent, dissolving many salts, alkalies, resins, alkaloids, essential oils, and other substances. It is used in pharmacy for making tinctures. By oxidation it gives aldehyde, CH_3COH, and then acetic acid, $C_2H_4O_2$. With chlorine it forms chloral (see Chloral). If alkalies are present, chloroform is produced.

What are its medicinal properties?

It acts on the body as a narcotic poison, but in small quantities as a stimulant. It is an antiseptic, and is used for the preservation of substances subject to decay.

COMMERCIAL SPIRITS, WINE, BEER.

What is meant by "proof spirit"?

The excise proof spirit has a specific gravity of 0.918 at 60° F., and contains 49¼ per cent. of pure alcohol.

Mention the educts and products of the fermentation of sugar, with quantities of each.

Educts	Glucose,	100.0	Products	Alcohol,	48.5	95
	Albumenoids,	1.0		Carbonic acid,	46.5	
	Salts,	.5		Glycerine,	3.6	
	Yeast,	.5		Salts,	.7	
				Fusel oil,	.7	
				Yeast,	2.0	

What is "fermentation"?

The production of alcohol by the decomposition of sugars or starches (vinous fermentation).

Mention the other kinds of fermentation, with their products.

Vinous produces wine;
Acetous " vinegar (acetic acid);
Lactous " sour milk (lactic acid);
Butyrous " sour butter (butyric acid).

Name the different ferments.

Diastase, ptyaline, pepsine, pancreatine, peptase, and tripsone.

What gives wines and beers their intoxicating properties?

The alcohol they contain.

About what proportion of alcohol is found in these beverages?

Port and sherry wine	19–25 per cent. alcohol.
Light wines (French and German)	12–18 " "
Strong ale	10 " "
Brandy, whiskey, gin, etc.	40–50 " "

How is wine made?

It is made by allowing the sweet juice of the grape to ferment until all or part of the sugar is converted into alcohol.

What are "sweet wines"?

Wines that contain a large proportion of sugar after they are made are called "sweet wines."

What are "dry wines"?

If most of the sugar has been converted into alcohol, they are called "dry wines."

If the wine is bottled before the fermentation is complete, an effervescent wine is produced.

What is beer, and how is it made?

Beer is a well-known beverage prepared from germinated grain, generally barley or starchy substances. The starch is converted into glucose by the diastase produced by heating the grain until it germinates. An infusion of the grain is then made, and this is boiled with about three per cent. of hops, and then cooled and run into vats and allowed to ferment. When the fermentation has gone far enough, the beer is drawn off and put into barrels.

How does vinous fermentation assist in making bread?

The yeast added to the dough converts the sugar in the meal into alcohol and carbonic acid, which by the heat of the oven, in their endeavor to expand, force the particles of dough apart and make the bread light.

What is leaven?

Leaven is dough in a state of putrefaction, and it may be used in place of yeast to start fermentation.

What are distilled liquors?

They are liquors obtained by distilling alcohol from the fermentation products of various substances which impart particular properties, as taste and smell, to the alcoholic distillate.

Mention some of the distilled liquors, with the preparation of each.

Brandy, made by distilling wine or cider, and coloring and flavoring the alcoholic distillate.

Rum, made by distilling fermentated molasses, from which it obtains its smell and taste.

Gin is made by distilling alcohol with juniper berries, but no coloring-matter is added.

Whiskey is generally obtained from rye, corn, or potatoes. The product of fermentation is freed from "fusel oil" as much as possible by distillation and filtration through charcoal, and then colored with caramel.

What is ethyl ether ($C_4H_{10}O$)?

This is the most important compound of this class and is generally called "ether" or sulphuric ether.

How is it prepared?

(1) It can be made by heating sodium ethylate with ethyl iodide:—

$$C_2H_5ONa + C_2H_5I = C_2H_5O{-}C_2H_5 + NaI.$$

(2) The best method, and the one used for preparing it on a large scale, is to heat alcohol and sulphuric acid to 140° C. The sulphuric acid abstracts one molecule of water from two of alcohol and gives one of ether:—

$$2C_2H_5OH + H_2SO_4 = (C_2H_5)_2O + H_2SO_4, H_2O.$$

The mixture is distilled, and ether, water, and alcohol are caught in the distillate; the latter is removed by washing and the ether separated from the water, being specifically lighter, and rectified by distillation.

What are the properties of ether?

It is a clear colorless liquid, specific gravity 0.792 at 15.5° C. It boils at 35° C. and has never been frozen. If dropped upon the hand, it produces the sensation of cold by its rapid evaporation. It is very combustible and its vapor mixed with air gives an explosive mixture. It should never be used near a naked flame. It is soluble in alcohol, but only slightly in water. It is one of the best solvents for oils and fats, and it also dissolves phosphorus and sulphur. It is not attacked by sodium and many other reagents. It is used also for dissolving gun-cotton in the preparation of collodion, which is used in surgery for covering wounds, but a mixture of alcohol and ether is more advantageous for this purpose. It is used in medicine as an anæsthetic, and is said to be less dangerous than chloroform.

What are thio alcohols and ethers?

They are alcohols or ethers in which the oxygen of the compounds has been replaced by sulphur :—

C_2H_5OH,	C_2H_5SH,	$C_2H_5O—C_2H_5$,	$C_2H_5S—C_2H_5$,
Ethyl alcohol.	Ethyl mercaptan. Ethyl sulphydrate.	Ether.	Ethyl sulphide.

Similar compounds of selenium and tellurium are also known, but they cannot be considered in this work.

Mention the most important compound ethers or esters of ethyl alcohol and how prepared.

The preparation of the esters has been given in the first part of Alcohols. The most important are :—

Ethyl nitrite, $C_2H_5NO_2$, which is used in medicine under the name of "sweet spirits of nitre," but in this mixture alcohol and aldehyde are also present.

Other esters of ethyl alcohol are :—

Ethyl nitrate	$C_2H_5NO_3$;
" sulphate	$(C_2H_5)_2SO_4$;
" acetate	$C_2H_5C_2H_3O_2$;
" valerate	$C_2H_5C_5H_{10}O_2$, etc.

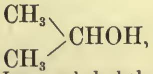
What is the next alcohol in the series?

Proypl alcohol, C_3H_7OH.

This formula can have two isomeric modifications :—

$$CH_3—CH_2—CH_2OH,$$

Propyl alcohol.



$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!CHOH,$$

Isopropyl alcohol.

The normal alcohol is found associated with ethyl alcohol from vinous fermentation. Both may be obtained by synthetic methods. They are like ethyl alcohol in many of their properties, but boil at higher temperatures.

What is the next alcohol of this series?

Butyl alcohol, $C_4H_{10}O$.

Four alcohols correspond to this formula: Two primary, one secondary, and one tertiary.

How are they obtained?

They can all be formed by synthetic processes. The isobutyl, $(CH_3)_2=CH—CH_2OH$, is one of the products of the fermentation of beet-root molasses. It also occurs in "coal oil" and American petroleum.

What are their properties?

They are like the preceding in their properties, but boil at higher temperatures and are more oily in appearance. Ethers and esters derived from them are known.

What is the next alcohol of the series?

The next is amyl alcohol, $C_5H_{11}OH$.

There are eight alcohols corresponding to this formula, and all but one have been synthetically prepared.

Which is the most important?

The isoamyl, called "amyl alcohol," is the principal constituent of "fusel oil" or "potato spirit." It is formed during the distillation of potatoes or corn, and it is very difficult to separate it from the ethyl alcohol.

What is the composition of "fusel oil"?

Propyl alcohol	C_3H_7OH;
Isobutyl "	C_4H_9OH;
Isoamyl "	$C_5H_{11}OH$;
Hexyl "	$C_6H_{13}OH$, etc.

What are the properties of amyl alcohol?

It is a colorless oily liquid, with a peculiar odor that causes coughing, and a burning taste. It is lighter than water, in which it is insoluble. It is soluble in alcohol and ether. It burns with a bright flame and may be used for illuminating purposes. It yields an aldehyde and isovaleric acid by oxidation. It is a violent poison, and gives the sharp burning taste to liquors. The following esters are used as flavorings, perfumes, and in medicine :—

Amyl acetate,	$C_5H_{11}C_2H_3O_2$,	used for "pear drops;"
" valerate,	$C_5H_{11}C_5H_{10}O_2$,	"apple oil;"
" nitrite,	$C_5H_{11}NO_2$,	used in medicine as a stimulant.

Mention some of the other alcohols belonging to this series.

Hexyl alcohol,	$C_6H_{13}OH$;	
Heptyl "	$C_7H_{15}OH$,	called œnanthic alcohol;
Octyl "	$C_8H_{17}OH$;	
Cetyl "	$C_{16}H_{34}O$,	obtained from spermaceti;
Ceryl "	$C_{27}H_{55}OH$,	" " Chinese wax;
Myricyl "	$C_{30}H_{61}OH$,	" " beeswax.

This last is the highest member of the series known.

From what are the unsaturated monatomic alcohols $C_nH_{2n-1}O$ derived?

They are olefines in which one hydrogen has been replaced by hydroxyl, C_2H_4—C_2H_3OH. The most important is allyl alcohol, C_3H_5OH, which occurs in the oil of mustard as an ester of isothiocyanic acid, C_3H_5NCS.

How can it be prepared?

By heating glycerine and oxalic acid together.

What are its properties?

It is a colorless, oily liquid, soluble in water, alcohol, and ether. It has a sharp, burning taste, is combustible, and when oxidized gives acrylic aldehyde (acrolein). It forms esters with the acids, and, being unsaturated, forms also additional products.

Crotyl alcohol, C_4H_7OH, is another alcohol of this series.

What other monatomic alcohols are known?

The only known alcohol is called propargyl alcohol, C_3H_3OH ($C_nH_{2n-2}O$), derived from the acetylene series.

What are glycols or diatomic alcohols ($C_nH_{2n+2}O_2$)?

They are paraffines in which two hydrogen atoms have been replaced by hydroxyl:—

$$\underset{\text{Ethane.}}{C_2H_6} - \underset{\text{Ethylene glycol.}}{C_2H_4(OH)_2}.$$

This is the lowest member of the series, because no compounds have been prepared in which one carbon atom has two hydroxyls, corresponding to methylene glycol, $CH_2(OH)_2$. Also no alcohol is known in which the hydroxyl is joined to an unsaturated carbon atom.

How are the glycols prepared?

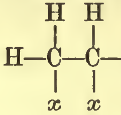
By decomposing the diatomic haloid ethers with silver oxide and water, or by making the diacetates and decomposing these with caustic alkalies:—

$$C_2H_4Cl_2 + Ag_2O,H_2O = C_2H_4(OH)_2 + 2AgCl;$$
$$C_2H_4C_2H_3O_2 + 2NaOH = C_2H_4(OH)_2 + Na_2C_2H_3O_2.$$

Caustic alkalies, acting on the haloid ethers, give unsaturated hydrocarbons.

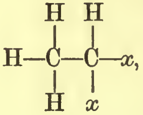
What are the properties of the glycols?

They are colorless, oily liquids without odor, but with a sweetish taste. Soluble in water, alcohol, and ether, ethylene glycol is insoluble in the latter alone. Oxidized, they give first mono- and then dibasic acids. Heated with haloid acids (except HI), they give hydrines $(C_2H_4OH)x$. They are like alcohol in many of their properties, but, being diatomic, they can form two classes of compounds:—



$$\begin{array}{ccccc} & & H & & H & \\ & & | & & | & \\ H & - & C & - & C & - H \\ & & | & & | & \\ & & x & & x & \end{array}$$

, ethylene compounds;



$$\begin{array}{ccccc} & & H & & H & \\ & & | & & | & \\ H & - & C & - & C & - x \\ & & | & & | & \\ & & H & & x & \end{array}$$

, ethylidine compounds;

What other glycols are known?

Propylene glycol, $C_3H_6(OH)_2$, 2 isomes;
Butylene " $C_4H_8(OH)_2$, 6 " two known;
Amylene " $C_5H_{10}(OH)_2$, one known.

What are triatomic alcohols?

They are hydrocarbons in which three hydrogen atoms have been replaced by three hydroxyls. Only one will be considered, namely, propenyl alcohol or glycerine, which occurs in natural fats combined with fatty acids as propenyl esters.

How is glycerine obtained?

It is obtained by boiling fat with caustic alkalies (saponification):—

$$\underset{\text{Stearine.}}{C_3H_5(C_{18}H_{35}O_2)_3} + 3KOH = \underset{\text{Glycerine.}}{C_3H_5(OH)_3} + \underset{\substack{\text{Potassium stearate}\\\text{(soap).}}}{3KC_{18}H_{35}O_2.}$$

The ester can be decomposed with superheated steam :—

$$\underset{\text{Stearine.}}{C_3H_5(C_{18}H_{35}O_2)_3} + 3H_2O = \underset{\text{Glycerine.}}{C_3H_5(OH)_3} + \underset{\text{Stearic acid.}}{3C_{18}H_{36}O_2}.$$

Glycerine is prepared by heating olive or other similar oil with oxide of lead. By this means an insoluble soap of lead is formed, called "lead plaster," which is used in medicine, under the name of diachylon, for the preparation of various plasters.

What are the properties of glycerine?

It is a thick, syrupy liquid, a little heavier than water, with a sweet taste. It is decomposed by boiling, giving acrolein. The pungent odor of burning fat is due to acrolein, C_3H_4O.

Dilute nitric acid on glycerine gives glyceric acid, $C_3H_6O_4$; concentrated, gives oxalic acid, $C_2H_2O_4$. If glycerine is added to a mixture of nitric and sulphuric acids, propenyl nitrate or "nitroglycerine" is produced :—

$$C_3H_5(OH)_3 + 3HNO_3 = C_3H_5(NO_3)_3 + 3H_2O.$$

This compound is a nitrate and not a nitro-compound, as generally called, and is a well-known explosive.

What are the properties of nitroglycerine?

It is, when pure, a colorless oil, heavier than water, with a sweet taste, but very pungent smell, which causes severe headache. It is a very poisonous substance when taken internally. It is used in medicine as a heart tonic.

Glycerine, like the glycols, forms esters and hydrines, but they are of no interest here.

What are tetratomic alcohols?

The only one known at present is erithrite, $C_4H_6(OH)_6$, also called erithromannite or phycite. It occurs in some plants, and is found in the decomposition-products of erithric acid.

What are its properties?

It is a crystalline compound, soluble in water, and, although it is a saccharine substance, it does not ferment.

Tetratomic alcohols with one carbon atom, $C(OH)_4$, have not been prepared; but ethers are known, $C(OC_2H_5)_4$, and they are called orthocarbonates.

What are the hexatomic alcohols?

They are hydrocarbons in which six atoms of hydrogen have been replaced by six hydroxyls, and under this class the saccharine substances occurring in plants and animals are considered.

Are all the sugars hexatomic alcohols?

Three of the natural sugars, mannite, dulcite, and sorbite, have the formula $C_6H_{14}O_6$, and are, therefore, hexatomic alcohols (saturated) derived from hexane. Others, called glucoses, have the formula $C_6H_{12}O_6$; that is, they contain two atoms less of hydrogen, and are therefore regarded as aldehydes of these alcohols. There are also saccharoses or diglucosic alcohols: $C_{12}H_{22}O_{11}$ (glucose, two molecules less one H_2O), anhydrides. Another class of compounds, called amyloses (amylum—starch), of the formula $C_6H_{10}O_5$, may be regarded as oxygen ethers or anhydrides of the glucoses, inasmuch as they differ from them by one molecule of water.

What are carbohydrates?

They are compounds of carbon, hydrogen, and oxygen, in which the hydrogen and oxygen are in the proportion to form water.

Give a classification of carbohydrates, with examples.

Glucoses, $C_6H_{12}O_6$.	Saccharoses, $C_{12}H_{22}O_{11}$.	Amyloses, $C_6H_{10}O_5$.
+ Dextrose, or grape-sugar.	+ Saccharose, cane-sugar.	+ Dextrine.
— Lævulose, fruit-sugar.	+ Maltose, malt-sugar.	+ Starch.
+ Galactose.	+ Trehalose.	+ Glycogen.
Inosite.	+ Lactose, milk-sugar.	— Inulin.
Sorbin.	Synanthose.	Cellulose.
		Gum.

Those marked + turn the plane of polarized light to the right, those marked — turn it to the left.

How do the carbohydrates occur?

Most of them occur in vegetable organisms, and a few in animal organisms. Dextrose exists ready formed in honey, fruits, especially grapes, and diabetic urine. Lævulose may be obtained by treating cane-sugar with dilute acids. If inulin is used instead of cane-sugar, pure lævulose is obtained. Inosite exists in muscular flesh; lactose in the milk of mammalia; the others are found in plants.

What are the properties of the glucoses?

The glucoses have the characteristic properties of alcohols, namely, that of forming esters by combination with acids and elimination of water. In their products of oxidation they differ slightly, most of them yielding saccharic acid ($C_6H_{10}O_8$), while some are not fermentable (inosite and sorbin). All, except inosite, are decomposed by boiling with aqueous solutions of alkalies. When boiled with an alkaline solution of potassiocupric tartrate, they precipitate red cuprous oxide.

Where is cane-sugar ($C_{12}H_{22}O_{11}$) found?

It is found in the juice of many grasses, in the root of the beet, in the sugar-maple, and in the "sugar-cane." In America it is principally obtained from the sugar-cane, in Europe from the sugar-beet.

How is the sugar extracted?

The sugar-cane contains about 18 per cent. of sugar, which is obtained by crushing out the juice and heating it with milk-of-lime to about 60° C. to remove albuminous matters. The juice is then allowed to boil, the scum removed from time to time, and the clear liquid evaporated in pans to a certain consistency, and allowed to crystallize. The crystals are drained from the molasses and sent into market under the name of "Muscovado sugar."

How is the sugar refined?

It is refined by redissolving in water, adding blood-albumen and lime-water, heating to boiling, and separating the coagulated albumen, which carries away with it all the mechanical impurities. The solution is decolorized by filtration through animal charcoal, evaporated to the crystallizing point, and poured into earthen moulds, when it solidifies to a cake, and is now called "loaf sugar."

What are vacuum pans?

They are closed vessels in which the concentration of the sugar is effected under a diminished pressure and at a low temperature, and by this means the quantity of molasses is greatly diminished.

At the present day a large quantity of sugar is extracted from the sugar-beet, but the process is more complicated and the yield much smaller than that for sugar-cane.

What are the properties of cane-sugar?

It crystallizes in monoclinic prisms. Its specific gravity is 1.6. It is very soluble in water and also in alcohol. It has a pure sweet taste and its uses are well known. When heated it melts to a glassy mass, known as "barley sugar." Heated higher, about 210° C., it loses some water and forms a brown mass called "caramel." Boiled with dilute acids it is converted into a mixture of dextrose and lævulose. Concentrated sulphuric acid absorbs water and gives carbon. It is easily oxidized and forms nitro compounds with concentrated nitric acid. Fehling's solution is slowly, but solutions of silver and mercury are rapidly, reduced by cane-sugar.

What are amyloses ($C_6H_{10}O_5$)?

They are oxygen-ethers or anhydrides of polyatomic alcohols. They have the general formula $C_6H_{10}O_5$, or some multiple of it, but their molecular formulæ have not yet been determined.

What is starch?

This is one of the most important of the vegetable principles, and it is found more or less in every plant.

How is starch obtained?

The seeds of the plant are crushed and then washed on a sieve with water. The cellular tissue remains, and the starch is carried through with the water, and settles out as an insoluble white powder.

What are its properties?

It is insoluble in cold, but dissolves in hot water. It is precipitated from its solutions by alcohol. It gives a blue color with iodine. It is an important article of food. Substances such as ordinary meal, arrowroot, sago, tapioca, and iceland moss are rich in starch.

What is glycogen ($C_6H_{10}O_5$)?

It is a substance found in the liver of several animals. It is obtained by extracting with water and precipitating by alcohol.

What is dextrine ($C_6H_{10}O_5$)?

It is a modified form of starch, obtained from the latter by boiling with an acid. It is a soluble, gum-like substance. It is sold under the name of "British gum" as a substitute for gum.

What is cellulose ($nC_6H_{10}O_5$)?

It is the woody portion of plants, and makes up their cells. Linen and cotton are very pure varieties of cellulose. It is not readily attacked by reagents or dissolved by ordinary solvents. It is soluble in a solution of ammonio-sulphate of copper. With nitric acid it yields an explosive compound called nitrocellulose or gun-cotton :—

(*a*) $C_{18}H_{21}(NO_2)_9O_{15}$, insoluble in alcohol and ether;
(*b*) $C_{18}H_{23}(NO_2)_7O_{15}$, soluble " " " "

What is nitrocellulose used for?

The first, (*a*) trinitrocellulose, is the most explosive, and is used for blasting.

The second (*b*) is used for making "collodion," by dissolving it in a mixture of alcohol and ether. Collodion is used in photography and by surgeons for covering wounds.

What is parchment paper?

It is a substance obtained by treating paper with sulphuric acid. It is like parchment, but has the same composition as cellulose.

Mention some of the important gums, with their uses?

Gum arabic: brought from Egypt and Arabia. It is soluble in water, and is used in medicine.

Mucilage: a gum abundant in linseed-oil and some roots. Its uses are well known.

Gum senegal is obtained from a tree growing in Senegal.

Gum tragacanth is found in America and Persia.

The last two are largely used for making paste for calico-printing.

What are amines?

The amines are hydrocarbons in which one or more hydrogen atoms have been replaced by amidogen, NH_2. They are called mon,- di-, triamines, according to the number of amido groups they contain. The monamines are also called primary amines. If one hydrogen of amidogen is replaced by an alkyl, the product is called a secondary amine; if both are replaced, they are called tertiary.

How are they formed?

(1) By the action of ammonia on the haloid ethers:—

$$C_2H_5Cl + NH_3 = C_2H_5NH_2 + HCl;$$

(2) By the reduction of alcoholic cyanides by hydrogen:—

$$CH_3CN + 2H_2 = CH_3 - CH_2NH_2.$$

What are their properties?

The amines are like ammonia in many of their properties, but are stronger bases and are combustible. The lower members are gases with an ammoniacal odor, and, like ammonia, they combine with haloid acids to form salts. The tertiary amines combine with haloid ethers to form ammonium bases; as, $(C_2H_5)_3NC_2H_5I$, called tetraethyl ammonium iodide.

How can primary, secondary, and tertiary amines be distinguished?

Primary + nitrous acid give alcohols;
Secondary + " " " nitroso compounds;
Tertiary + " " " no reaction.

What are the alkyl compounds of phosphorus, arsenic, antimony, and boron called?

These elements form compounds similar to amines, and are called, respectively, phosphines, arsines, stibines, and borines.

What are their properties?

They are very inflammable and poisonous compounds.

What are the silicon compounds?

Silicon forms compounds with alkyls; as, silicon tetramethyl, $Si(CH_3)_4$, etc.

Silicon, being a tetrad, is capable of forming a series of compounds similar to those of carbon, and many have been prepared :—

SiH_4, silicomethane ;
H_2SiO_3, silicon carbonic acid ;
C_2H_5SiOOH, silicopropionic acid.

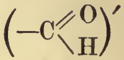
What are organo-metallic compounds?

They are compounds of alkyl radicals with metals.

Mention a few of these metallic compounds.

Zinc methyl	$(CH_3)Zn$;
Sodium ethyl	C_2H_5Na ;
Magnesium ethyl	$(C_2H_5)_2Mg$;
Mercury ethyl	$(C_2H_5)_2Hg$, etc.

What are aldehydes?

They are compounds containing the monovalent group  $\left(-C\begin{matrix}/\!\!/O\\ \backslash H\end{matrix}\right)'$ united to a hydrocarbon radical.

How are they prepared?

(1) By the oxdiation of primary alcohols :—

$$\underset{\text{Alcohol.}}{C_2H_5OH} + O = \underset{\text{Aldehyde.}}{C_2H_4O} + H_2O ;$$

(2) By distilling a mixture of the calcium salt of the corresponding fatty acid with calcium formate :—

$$Ca(CH_3CO_2)_2 + Ca(HCO_2)_2 = 2CH_3COH + 2CaCO_3.$$

Some of the aldehydes occur in the essential oils.

What are the properties of aldehydes?

They are colorless, neutral, volatile liquids, with a more or less pungent odor. The lower members are soluble in water. They oxidize in the air up to the corresponding acids. They precipitate metallic silver from an ammoniacal solution of silver nitrate, the silver being deposited on the walls of the vessel as a brilliant mirror. This property is utilized for silvering glass.

They combine with ammonia, bisulphites of the alkali metals, and hydrocyanic acid.

Mention a few of the aldehydes derived from the saturated monatomic alcohols.

Formic aldehyde,	CH_2O ;	Acetic aldehyde,	C_2H_4O.
Propionic aldehyde,	C_3H_6O ;	Butyric aldehyde,	C_4H_8O ;

Valeric aldehyde, $C_5H_{10}O$.

How is acetic aldehyde (C_2H_4O) ("aldehyde") prepared?

It is formed by the oxidation of ethyl alcohol, as already shown. It is found in large quantities with alcohol obtained from sugar-beet and potatoes, probably formed by the oxidation of the spirit during filtration through animal charcoal for the removal of fusel oil.

What are its properties?

It is a light colorless liquid with an ethereal odor. It mixes with water, alcohol, and ether. When exposed to the air it oxidizes to acetic acid; it also has the other properties of aldehydes. If breathed, it causes suffocation.

What is paraldehyde?

If aldehyde is allowed to stand with sulphuric acid in the cold, it polymerizes and forms a crystalline compound called paraldehyde. Its formula is probably $C_6H_{12}O_3$. It is used in medicine as an hypnotic. Chlorine acting on aldehyde or alcohol produces substitution-products, the most important of which is trichlor aldehyde.

What is chloral?

Chloral is trichlor aldehyde, CCl_3COH.

It was first prepared by Liebig by the action of chlorine on alcohol:—

$$(1)\ C_2H_5OH + Cl_2 = CH_3COH + 2HCl;$$
$$(2)\ CH_3COH + 3Cl_2 = CCl_3COH + 3HCl.$$

How is chloral prepared?

It is prepared by passing chlorine gas into absolute alcohol as long as hydrochloric acid gas is evolved. The product is agitated with sulphuric acid and distilled.

What are the properties of chloral?

It is a thin, oily, colorless liquid with a pungent odor. It is soluble in water, alcohol, and ether. It combines with water to form chloral hydrate, $CCl_3CH(OH)_2$, a crystalline compound, used in medicine as an anodyne and hypnotic.

What is bromal?

It is tribrom aldehyde, CBr_3COH.

Mention the unsaturated aldehydes.

Acrylic aldehyde (acrolein), C_3H_4O; Crotonic aldehyde, C_4H_6O.

How is acrolein formed?

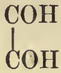
It is produced by the oxidation of allyl alcohol or by the destructive distillation of fats. The violent pungent odor produced by burning fat is due to acrolein.

What is croton chloral?

It is trichlor butyric aldehyde.

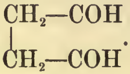
It is similar to chloral in many of its properties. Its hydrate is used in medicine as a hypnotic and an analgesic.

What other aldehydes are known?

Glyoxal  from glycol;

$$\begin{array}{l}\text{COH}\\ |\\ \text{COH}\end{array}$$

Aldol $C_4H_8O_2$ from butylene glycol;

Succinic aldehyde 

$$\begin{array}{l}\text{CH}_2\text{—COH}\\ |\\ \text{CH}_2\text{—COH}\end{array}.$$

What are ketones?

These bodies contain the group CO combined with two alkyl radicals, as:—

$$CH_3\text{—}CO\text{—}CH_3, \text{ methyl ketone.}$$

How are they prepared?

(1) By the oxidation of secondary alcohols:—

$$[\underset{\text{Isopropyl alcohol.}}{(CH_3)_2=CHOH}] + O = [\underset{\text{Acetone.}}{(CH_3)_2=C=O}] + H_2O;$$

(2) By distilling the calcium salt of the corresponding fatty acid:—

$$\underset{\text{Calcium acetate.}}{(CH_3COO)_2Ca} = CaCO_3 + \underset{\text{Acetone.}}{CH_3\text{—}CO\text{—}CH_3}.$$

What are their properties?

They are mostly volatile liquids, insoluble in water. They do not reduce an ammoniacal silver nitrate solution, and only a few combine with bisulphites. On oxidation they break up into different acids. Hydrogen reduces them to secondary alcohols.

What is acetone?

It is dimethyl ketone, CH_3COCH_3. It can be prepared by either of the above reactions, but it is generally prepared by the second.

It is found in crude wood-spirit, and it is separated by fractional distillation.

What are its properties?

It is a colorless limpid liquid with a pungent odor, lighter than water, and boils at 55° C. It is very inflammable and burns with a bright flame. It is miscible with water, alcohol, and ether in all proportions. It is largely used as a solvent for gums, oils, and resins.

When acetone is heated with sulphuric acid it forms mesitylene or trimethyl benzene, an aromatic compound ($C_6H_3(CH_3)_3$.

A derivative of acetone, called dimethyl ketone, diethyl sulphone, $(CH_3)_2C = (SO_2C_2H_5)_2$, is used in medicine, under the name of sulfonal, as a hypnotic; also diethyl sulphone, methyl ethyl ethane, trional, $CH_3C_2H_5 = C = (SO_2C_2H_5)_2$; and diethyl sulphone, diethyl methane, $(C_2H_5)_2 = C = (SO_2C_2H_5)_2$, tetronal, which are used for the same purpose.

What are organic acids?

They are hydrocarbons in which one or more hydrogen atoms have been replaced by carboxyl or oxatyl $(COOH)'$.

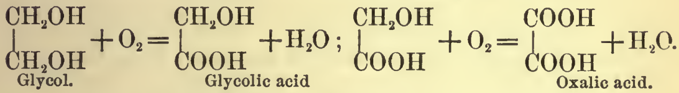
They are mono-, di-, or tribasic according to the number of carboxyls they contain, and mono-, di-, or triatomic according to the number of hydroxyls they contain :—

Acetic acid, CH_3COOH, monobasic, monatomic;
Lactic " $CH_3—CHOHCOOH$, monobasic, diatomic;
Malonic " $CH_2(COOH)_2$, dibasic, diatomic.

How are the organic acids formed?

By the oxidation of primary alcohols :—

$$\underset{\text{Alcohol.}}{CH_3—CH_2OH} + O_2 = \underset{\text{Acetic acid.}}{CH_3—COOH} + H_2O;$$



$$\underset{\text{Glycol.}}{\begin{matrix}CH_2OH\\ |\\ CH_2OH\end{matrix}} + O_2 = \underset{\text{Glycolic acid}}{\begin{matrix}CH_2OH\\ |\\ COOH\end{matrix}} + H_2O;\ \begin{matrix}CH_2OH\\ |\\ COOH\end{matrix} + O_2 = \underset{\text{Oxalic acid.}}{\begin{matrix}COOH\\ |\\ COOH\end{matrix}} + H_2O.$$

Give some of the compounds into which acids may be changed.

The replacement of the hydrogen atom in carboxyl by a metal gives a salt (CH_3COONa, sodium acetate); by an alkyl radical, an ethereal salt or ester ($CH_3—COO—CH_3$, methyl acetate or methyl acetic ester); by an acid radical, an acid anhydride ($CH_3COO—COCH_3$, acetate anhydride). If the hydroxyl is replaced by a halogen, an acid haloid is formed (CH_3COCl, acetyl chloride); and if by amidogen, an amide is formed (CH_3CONH_2, acetamide).

From what are monatomic acids (monobasic), $C_nH_{2n}O_2$, derived?

These acids are derived from the monatomic alcohols by the substitution of O for H_2, and for each series of hydrocarbons and alcohols there are corresponding acids :—

Hydrocarbon.	Alcohol.	Acid.
$H—CH_2—H$. Methane.	$H—CH_2OH$. Methyl alcohol.	$H—COOH$. Formic acid.

What are fatty acids?

The acids are so-called because they are mostly derived from fats, etc., and, except the three lowest of the series, they are oily liquids or fat-like substances.

Mention some of the important fatty acids, with the source of each.

Name.	Formula.	Source.
Formic acid,	HCO_2H,	From red ants.
Acetic acid,	CH_3CO_2H,	“ vinegar.
Propionic acid,	$C_2H_5CO_2H$,	“ putrid cheese.
n-Butyric acid,	$C_2H_5CH_2CO_2H$,	“ cows' butter.
Isobutyric acid,	$(CH_3)_2CHCO_2H$,	“ parsnip oil.
Isovaleric acid,	$(CH_3)_2=CH—CH_2—CO_2H$,	“ valerian root.
Palmitic acid,	$C_{15}H_{31}CO_2H$,	“ palm oil.
Margaric acid,	$C_{16}H_{33}CO_2H$,	Does not occur in nature.
Stearic acid,	$C_{17}H_{35}CO_2H$,	From beef and mutton fat.

All the acids above propionic have isomeric modifications. Some occur free, but many as salts and esters. The glycerine esters of palmitic and stearic acids are known as natural fats. Ceryl esters are waxes.

How are these acids prepared?

(1) By the oxidation of monatomic alcohols, by exposing the latter to air in the presence of certain ferments.

(2) By the treatment of alcohols and aldehydes by oxidizing agents (chromic acid, etc.).

(3) By the action of carbon dioxide on alkyl metals :—

$$CO_2 + \underset{\text{(Sodium ethyl.)}}{C_2H_5Na} = \underset{\text{(Sodium propionate.)}}{C_2H_5CO_2Na.}$$

(4) By boiling the cyanides with aqueous alkalies or acids (saponification):—

$$HCN + KOH + H_2O = HCO_2K + NH_3;$$
$$CH_3CN + HCl + 2H_2O = CH_3CO_2H + NH_4Cl.$$

What are their general properties?

The lower members are colorless liquids, the intermediate are thick, oily liquids, the higher ones crystalline solids. Most are insoluble in water, but dissolve in alcohol. They combine with the metals to form salts, and with the alcohols to form esters.

The alkaline-earth salt of a fatty acid heated with the same salt of formic acid gives an aldehyde; heated alone it gives a ketone.

How is formic acid (HCO_2H) prepared?

It occurs, as already mentioned, in the bodies of red ants, and may be obtained from them by distilling with water. It can be prepared by any of the general methods.

What are its properties?

It is a colorless liquid which fumes in the air, and has a very penetrating odor. Its vapor is inflammable. It is very corrosive and produces blisters and painful sores on the skin. It mixes with water, alcohol, and ether. It is a powerful reducing agent. Some of its salts are:—

Potassium formate, HCO_2K; Calcium formate, $(HCO_2)_2Ca$;
Ethyl ortho formate, $HC(C_2H_5O)_3$.

How is acetic acid ($C_2H_4O_2$) prepared?

It is found in small quantities in the juices of plants and animals. It can be produced by any of the general methods, but in particular by the slow oxidation (fermentation) of ethyl alcohol:—

$$\underset{\text{(Alcohol.)}}{CH_3—CH_2OH} + O_2 = \underset{\text{(Acetic acid.)}}{CH_3COOH} + H_2O.$$

It is also obtained by the destructive distillation of wood.

What is vinegar, and how is it prepared?

Vinegar is a dilute solution of acetic acid. It is prepared by mixing dilute alcohol with a little yeast and exposing it to the air until completely oxidized. The best vinegar is made from wine. To prevent the vinegar from "mothering" a little sulphuric acid is frequently added.

What is glacial acetic acid?

Pure acetic acid is obtained by distilling sodium acetate with sulphuric acid. The acid is redistilled and allowed to cool, when crystals of the pure acid separate out. They are drained from the mother liquor and constitute glacial acetic acid.

What are its properties?

Acetic acid below 15° C. is a crystalline solid, above that temperature it is a thin colorless liquid, with a pungent smell and a fiery taste. It blisters the skin. Its vapor is inflammable. It is miscible with water, alcohol, and ether, and dissolves some gums and resins. It is used in medicine as a cauterizing agent, but before using should always be examined for copper and lead, as these metals are often derived from the apparatus in which it is prepared. It forms salts and esters which are largely used in the arts.

Mention some of its salts and esters.

Sodium acetate, $CH_3CO_2Na,3Aq$.

Ammonium acetate, $CH_3CO_2NH_4$. A solution of this salt is used in pharmacy and is known as "Spiritus Mindereri."

Aluminium acetate, $(CH_3CO_2)_6Al_2$, is largely used as a mordant in dyeing and calico-printing, and for making "lakes" or pigments.

Acetate of lead, $Pb(C_2H_3O_2)_2 3Aq$.

Basic acetate of lead, $2Pb(C_2H_3O_2)_2PbO$. A solution of this salt is used in pharmacy under the name of Goulard water.

Acetate of copper (basic), $2Cu(C_2H_3O_2)_2,CuO,6Aq$, called "verdigris," is a very poisonous salt, and, therefore, copper vessels used for cooking should always be well cleansed before using.

Ethyl acetate, $C_2H_5C_2H_5O_2$.

Amyl acetate, $C_5H_{11}C_2H_3O_2$. This last is used as a flavor, having an odor like Jargonelle pears.

Mention some of the derivatives of acetic acid.

Acetyl chloride, C_2H_3OCl;

Acetic anhydride $(C_2H_3O)_2O$;

Chloracetic acid, CH_2ClCO_2H. This last is used in medicine as a cauterizing agent.

What other acids of this series are important?

The other acids are mentioned in the table. Neuric and œnanthic acids form esters that are used as flavoring extracts.

Pelargonic acid, $C_9H_{18}O_2$, is found in geranium leaves.

Capric acid, $C_{10}H_{20}O_2$, is found in butter.

Lauric acid, $C_{12}H_{24}O_2$, is found in fat of the bay-tree.

Myristic acid, $C_{14}H_{28}O_2$, is found in nutmeg butter.

Palmitic acid, $C_{16}H_{32}O_2$. This occurs as a glyceride in many natural fats, as palm-oil, Chinese tallow, and Japan-wax. It is easily prepared by saponifying the fat with caustic alkalies or superheated steam.

What are its properties?

It is a colorless solid, without taste or smell. It forms salts and esters.

Margaric acid, $C_{17}H_{34}O_2$. This acid does not occur in nature, but can be formed synthetically.

Stearic acid, $C_{18}H_{36}O_2$. It is found abundantly in beef and mutton suet, but exists in many other fats, and can be obtained by the same method as used for palmitic acid. It is like the latter in its properties.

What are soaps?

They are alkali salts of fatty acids (like palmitic, stearic, and oleic). The salts of the heavy metals are called plasters ("lead plaster").

What are "hard" and "soft" soaps?

If the soap is made with potash, it is called "soft" soap; if with soda, "hard" soap.

Stearic acid is largely used for making candles.

Mention some other acids of this series.

Arachidic acid, $C_{20}H_{40}O_2$: in oil of the earth-nut;
Benic acid, $C_{22}H_{44}O_2$: from the oil of ben;
Cerotic acid, $C_{27}H_{54}O_2$: in beeswax;
Melissic acid, $C_{30}H_{60}O_2$: from myricyl alcohol.

Give a list of the monatomic (unsaturated) acids $C_nH_{2n-2}O_2$.

Acrylic acid, $C_3H_4O_2$; Angelic acid, $C_5H_8O_2$;
Crotonic acid, $C_4H_6O_2$; Oleic acid, $C_{18}H_{34}O_2$.

How are they formed?

They are formed by methods similar to those used for the preceding acids. They can be derived from the latter by the removal of two atoms of hydrogen. Propionic acid, $C_3H_6O_2$, gives (less H_2) acrylic acid, $C_3H_4O_2$. Also by dehydrating oxy-acids:—

$$\underset{\text{Lactic acid.}}{CH_3\text{—}CHOH\text{—}COOH} \text{ gives } \underset{\text{Acrylic acid.}}{CH_2\text{—}CHCOOH} + H_2O.$$

What are their properties?

They are like the saturated acids in many of their properties, but are distinguished by their ability to take up additional atoms to form saturated compounds. When fused with alkalies or oxidized, they split and form lower acids.

How is oleic acid ($C_{18}H_{34}O_2$) prepared?

This acid is the most important member of the series. It occurs in the liquid portion of many fats as a glycerine ester, and can be obtained by saponification of the oleine, which is a by-product from the manufacture of stearine candles.

What are its properties?

It is a liquid at the ordinary temperature, but solidifies at about 4° C. It has neither taste nor smell, and reacts neutrally. It slowly oxidizes in the air, and becomes "rancid" when heated.

It forms salts and esters. Its glycerine ester is called oleine. Oleine of animal fats, olive oil, and some others do not dry in the air. They are "non-drying oils." Oleic acid treated with nitrous acid passes into a solid isomer called *elaidic acid.*

What are drying oils?

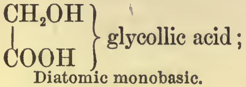
They are glycerides of linoleic acid, from linseed, poppy, hemp, etc.

What are the monatomic monobasic (unsaturated) acids $C_nH_{2n-4}O_2$?

These acids correspond to the acetylenes. The lowest of the series is tetrolic acid, $C_4H_4O_2$.

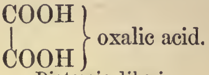
What are the diatomic, monobasic, and dibasic acids $C_nH_{2n}O_3$ and $C_nH_{2n-2}O_4$?

These acids contain two hydroxyl groups, and may be mono- or dibasic :—



$$\left.\begin{array}{l}CH_2OH\\ |\\ COOH\end{array}\right\}\text{ glycollic acid;}$$

Diatomic monobasic.



$$\left.\begin{array}{l}COOH\\ |\\ COOH\end{array}\right\}\text{ oxalic acid.}$$

Diatomic dibasic.

How are the monobasic acids prepared?

(1) By the limited oxidation of glycols :—

$$CH_2OH{-}CH_2OH + O_2 = CH_2OH - COOH + H_2O\,;$$

(2) By treating the halogen fatty acids with silver oxide and water :—

$$2CH_2ClCO_2H + Ag_2O, H_2O = 2CH_2OHCO_2H + 2AgCl\,;$$

By further oxidation these acids become dibasic :—

$$\underset{\text{Glycollic acid.}}{CH_2OHCOOH} + O_2 = \underset{\text{Oxalic acid.}}{COOH - COOH} + H_2O.$$

Give a list of the monobasic acids.

Carbonic acid,	CH_2O_3 (does not exist free);
Glycollic acid,	$C_2H_4O_3$;
Lactic acid, (both)	$C_3H_6O_3$;
Oxybuytric acid,	$C_4H_8O_3$;
Oxyvaleric acid,	$C_5H_{10}O_3$, etc.

All, except the first and second, form isomeric compounds. They are all monobasic except carbonic acid, which forms salts corresponding to dibasic acids. It will be considered last.

Lactic acid, $C_3H_6O_3$. Two acids (α and β) are possible for this formula: the α or ethidene lactic acid only will be considered (α and β refer to the position of hydroxyl).

What is ordinary lactic acid?

Ordinary or α-lactic acid is produced from sugar by a particular ferment. It occurs in sour milk. It can be produced synthetically.

What are its properties?

It is a syrupy liquid, intensely sour. It is soluble in water, alcohol, and ether. It forms salts and esters.

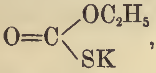
What are para- and sarco-lactic acids?

They are modifications of α-lactic acid existing in the muscular flesh of animals.

FREE carbonic acid, H_2CO_3, is not known, as it always decomposes into CO_2 and H_2O when liberated from its compounds. Being bibasic, it forms acid and normal salts and esters. If the oxygen atoms are replaced by sulphur, a series of acids called thiocarbonic acids are produced :—

$CS(HS)_2$.	$S{=}CHSHO$.	$O{=}C(SH)_2$.
Thiocarbonic acid.	Thiosulphocarbonic acid.	Dithiocarbonic acid.
(Free acid known.)	(Free acid unknown.)	(Free acid unknown.)

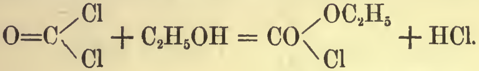
The esters of thiosulphocarbonic acid are called xanthogenates :—



$$O{=}C\begin{matrix}\diagup OC_2H_5\\ \diagdown SK\end{matrix}$$, ethyl potassium xanthogenate.

How are carbonic esters produced?

They are formed by the action of carbonyl chloride on alcohol :—

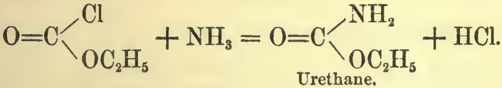


$$O{=}C\begin{matrix}\diagup Cl\\ \diagdown Cl\end{matrix} + C_2H_5OH = CO\begin{matrix}\diagup OC_2H_5\\ \diagdown Cl\end{matrix} + HCl.$$

Ethyl chlorcarbonate.

What are urethanes?

If chlorcarbonic esters are treated with ammonia, esters of carbamic acid (urethanes) are formed :—



$$O{=}C\begin{matrix}\diagup Cl\\ \diagdown OC_2H_5\end{matrix} + NH_3 = O{=}C\begin{matrix}\diagup NH_2\\ \diagdown OC_2H_5\end{matrix} + HCl.$$

Urethane.

What are the properties of urethanes?

They are white, crystalline, volatile substances, soluble in water, alcohol, and ether, used in medicine as hypnotics.

Give a list of the diatomic dibasic acids $C_nH_{2n-2}O_4$, and their sources.

Oxalic acid,	$C_2H_2O_4$,	in sorrel grass;
Malonic acid,	$C_3H_4O_4$,	in the residue from beet-sugar;
Succinic acid,	$C_4H_6O_4$,	in amber, brown coal, etc.;
Pyrotartaric acid,	$C_5H_8O_4$,	by distilling tartaric acid;
Adipic acid,	$C_6H_{10}O_4$,	by the oxidation of fats;
Suberic acid,	$C_8H_{14}O_4$,	by the action of HNO_3 on cork;
Sebacic acid,	$C_{10}H_{18}O_4$,	by distilling oleic acid.

How are these acids formed?

(1) By the oxidation of the corresponding glycols:—

$$\underset{\text{Glycol.}}{C_2H_4(OH)_2} + 2O_2 = \underset{\text{Oxalic acid.}}{(COOH)_2} + 2H_2O.$$

(2) By saponification of the cyanides of the olefines (boiling with KOH or HCl):—

$$C_2H_4(CN)_2 + 4H_2O = C_2H_4(COOH)_2 + 2NH_3.$$

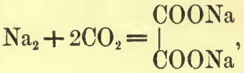
What are their properties?

They are crystalline bodies, generally not decomposed by heat, and not forming anhydrides. Easily soluble in water, the solution reacting strongly acid. All above malonic have isomeric modifications.

How is oxalic acid ($C_2H_2O_4$) obtained?

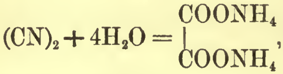
It occurs in plants as potassium and other salts. It can be obtained by the oxidation of sugar, cellulose, etc., also synthetically.

(1) By the action of CO_2 on sodium:—



$$Na_2 + 2CO_2 = \begin{array}{l} COONa \\ | \\ COONa \end{array}, \text{ sodium oxalate.}$$

(2) By the action of H_2O on cyanogen:—



$$(CN)_2 + 4H_2O = \begin{array}{l} COONH_4 \\ | \\ COONH_4 \end{array}, \text{ ammonium oxalate.}$$

What are its properties?

It forms crystals with $2H_2O$. It is soluble in water, and the solution is strongly acid. It sublimes without decomposition, but if heated over 200° C. or with concentrated H_2SO_4 it breaks up into CO, CO_2, H_2O. It forms salts and esters. The soluble salts and the free acid are very poisonous. Its antidote is lime-water.

How is succinic acid ($C_4H_6O_4$) obtained?

Its occurrence has already been given. It can be made by synthesis from ethylene cyanide:—

$$C_2H_4(CN)_2 + 4H_2O = C_2H_4(COOH)_2 + 2NH_3.$$

What are its properties?

It is a crystalline compound soluble in water. It forms acid and neutral salts and esters. The normal acid forms an anhydride, the iso acid does not.

Mention some of the unsaturated acids $C_nH_{2n-4}O_4$.

Fumaric acid,	$C_4H_4O_4$,	free in Iceland moss and fungi;
Maleic acid,	$C_4H_4O_4$,	by heating malic acid;
Itaconic acid,	$C_5H_6O_4$,	by distilling citric acid;
Hydromucic acid,	$C_6H_8O_4$.	

What are the triatomic monobasic acids $C_nH_{2n}O_4$?

The only acid is glyceric, $C_3H_6O_4$, obtained by the oxidation of glycerine with HNO_3.

What are the triatomic bibasic acids $C_nH_{2n-2}O_5$?

Tartionic acid, $C_3H_4O_5$;
Malic acid, $C_4H_6O_5$, found in apples, pears, etc.;
Oxypyrotartaric, $C_5H_8O_5$;
Oxyadipic, $C_6H_{10}O_5$.

How is monoxysuccinic or malic acid ($C_4H_6O_5$) prepared?

It occurs free in apples and pears, and is often associated with citric acid. It can be prepared synthetically from monobromsuccinic acid:—

$$2C_2H_3Br(COOH)_2 + Ag_2O, H_2O = 2C_2H_3OH(COOH)_2 + 2AgBr.$$

What are its properties?

It is a crystalline compound soluble in water and alcohol. Heated over 100° C. it loses water and becomes fumaric acid. Three acids are known, an inactive and two active (+ and —).

Mention some of the triatomic tribasic acids $C_nH_{2n-4}O_6$.

Tricarballylic acid, $C_6H_8O_6$;
Aconitic acid (unsaturated), $C_6H_6O_6$, occurs in "monk's hood";
Meconic acid (unsaturated), $C_7H_4O_7$, occurs in opium.

Mention some of the tetratomic bibasic acids $C_nH_{2n-2}O_6$.

Dioxymalonic acid,	$C_3H_4O_6$;	
+ Tartaric acid,	$C_4H_6O_6$,	occurs in grapes;
Homotartaric acid,	$C_5H_8O_6$;	
Citric acid,	$C_6H_8O_7$,	occurs in lemons, currants, etc.

Tartaric tribasic acid, $C_4H_6O_6$. Four acids are known corresponding to this formula, viz.:—

(1) Dextrotartaric acid;
(2) Lævotartaric acid;
(3) Paratartaric acid, or racemic acid;
(4) Inactive tartaric acid.

What is ordinary tartaric acid, and how is it prepared?

Ordinary or dextro (+) tartaric acid occurs in grapes, pineapples, etc., as a potassium salt. It is prepared from argol (acid potassium tartrate) deposited from wine. It can also be prepared synthetically from dibromsuccinic acid.

What are its properties?

It is a crystalline compound soluble in water, with a pure acid taste and reaction. Heated to a high temperature it loses water, and there remains a carbonaceous residue that smells like burnt sugar (a test).

Mention some of its compounds and their uses.

The acid is used in medicine and for calico-printing.

Cream of tartar,	$KHC_4H_4O_6$,	for baking-powders;
Rochelle salts,	$KNaC_4H_4O_6$,	used in medicine as a purgative;
Tartar emetic,	$KSbOC_4H_4O_6$,	used in medicine as an emetic.

Other salts and esters are also used.

How is citric acid ($C_6H_8O_7$) obtained?

It occurs in large quantities in lemons, currants, and other fruits. It can be formed by synthesis.

What are its properties?

It crystallizes in two forms, has an agreeable taste, and is soluble in water. It is easily decomposed by strong acids. It forms salts and esters.

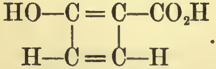
Mention some of its salts and their esters.

Citrate of magnesium, $MgC_6H_6O_2$, used in medicine as a purgative. Ammonio-ferric citrate, used in photography.

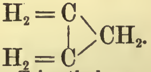
What other organic acids may be mentioned?

Apsorbic acid,	$C_5H_8O_7$,	by the action of HNO_3 on sorbin;
Gluconic acid,	$C_6H_{12}O_7$,	" oxidation of grape-sugar;
Mannitic acid,	$C_6H_{12}O_7$,	" oxidation of mannite;
Saccharic acid,	$C_6H_{10}O_8$,	" action of dilute HNO_3, on cane-sugar;
Mucic acid,	$C_6H_{10}O_8$,	" action of dilute HNO_3, on gums;
Pyromucic acid,	$C_5H_4O_3$,	" dry distillation of mucic acid.

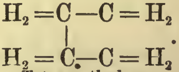
What is the constitution of pyromucic acid, and what substances are related to it?



Pyromucic acid.



Trimethylene.

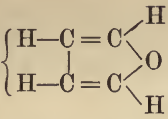


Tetramethylene.

All these have closed chains.

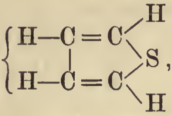
There are also :—

Furfuran, C_4H_4O



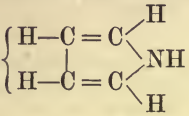
, occurs in pine-tar;

Thiophene, C_4H_4S



, occurs in coal-tar;

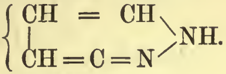
Pyrrol, C_4H_5N



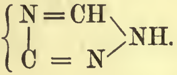
, occurs in bone-tar.

Tetraiodopyrrol, called "iodol," C_4I_4NH, is used as an antiseptic. "Pyrrol-red" is a dye-stuff, $C_{12}H_{14}N_2O$, from pyrrol.

Pyrazol, $C_3H_4N_2$



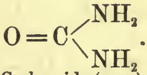
Triazol, $C_2H_2N_3$



What are amides?

They are ammonia in which one or all the hydrogens have been replaced by acid radicals, thus:

$$\underset{\text{Acetamide.}}{CH_3—CO—NH_2};$$



Carbamide (urea).

Like amines, they may be primary, secondary, and tertiary. They combine with acids to form salts.

How are amides of the monatomic acids $C_nH_{2n+1}OH$ prepared?

(1) By the dry distillation of the ammonium salt :—

$$\underset{\text{Ammonium acetate.}}{C_2H_3O_2NH_4} = \underset{\text{Acetamide.}}{C_2H_3ONH_2} + H_2O.$$

(2) By the action of ammonia on acid chlorides or esters :—

$$C_2H_3OCl + NH_3 = C_2H_3ONH_2 + HCl;$$
$$C_2H_3—O_2C_2H_5 + NH_3 = C_2H_3ONH_2 + C_2H_5OH.$$

What are their properties?

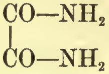
Most of them are crystalline compounds soluble in alcohol and ether. The lower ones are soluble in water. They distil without decomposition and are not so stable or basic as the amines. Boiling with caustic alkalies decomposes them.

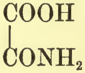
Mention some of the important amides.

Formamide,	$H-CONH_2$;
Acetamide,	CH_3CONH_2;
Glycolamide,	$CH_2OHCONH_2$;
Lactamide,	$CH_3CHOHCONH_2$.

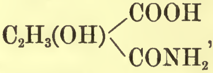
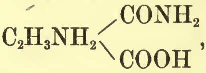
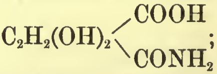
What are amic acids?

In di- or poly-basic acids, one or all the hydroxyls may be replaced by amidogen. If all are replaced, the compounds are called amides; if some only are replaced, they are called amic acids:—

Amide,  $\begin{array}{l} CO-NH_2 \\ \vert \\ CO-NH_2 \end{array}$ oxamide;

Amic acid,  $\begin{array}{l} COOH \\ \vert \\ CONH_2 \end{array}$ oxamic acid.

Mention some of the amides of polybasic acids?

Malamide,	$C_2H_3(OH)(CONH_2)_2$;
Malamic acid,	 $C_2H_3(OH){<}\begin{array}{l} COOH \\ CONH_2 \end{array}$, not known free;
Aspartic acid,	$C_2H_3NH_2=(COOH)_2$, found in beet-root molasses;
Asparagin,	 $C_2H_3NH_2{<}\begin{array}{l} CONH_2 \\ COOH \end{array}$, found in asparagus;
Tartramide,	$C_2H_2(OH)_2=(CONH_2)_2$;
Tartramic acid,	 $C_2H_2(OH)_2{<}\begin{array}{l} COOH \\ CONH_2 \end{array}$;
Citramide,	$C_3H_4(OH)(CONH_2)_3$;
Carbamide,	$CO(NH_2)_2$, (urea) in urine.

What is urea (CH_4N_2O), and how is it prepared?

The history and preparation of urea have been given in the Introduction.

(1) It can also be formed by the action of carbonyl chloride on ammonia:—

$$COCl_2 + 2NH_3 = CO(NH_2)_2 + HCl.$$

(2) By heating cyanamide with water:—

$$CNNH_2 + H_2O = CO(NH_2)_2.$$

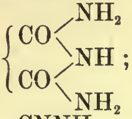
How is urea obtained from urine?

The urine (best from cows or horses, as it contains more urea than human urine) is treated with sulphuric acid, and the salt of urea allowed to crystallize out. It is then decomposed with an alkali, and the urea extracted with alcohol and the solution allowed to crystallize.

What are its properties?

Urea forms transparent crystals, soluble in water and alcohol. It has no smell, but a saline taste. When heated it forms a large number of decomposition-products, some of which are the following:—

Biuret,



$$\left\{\begin{array}{l}\mathrm{CO}<^{\mathrm{NH_2}}_{\mathrm{NH}}\\ \mathrm{CO}<^{\mathrm{NH}}_{\mathrm{NH_2}}\end{array}\right.;$$

Cyanamide, $CNNH_2$;
Cyanamic acid, $C_3H_3N_3O_3$.

Others are produced, depending on the temperature of the operation.

Urea forms salts with acids by combining directly with them:—

Nitrate of urea,	$CO(NH_2)_2HNO_3$;
Hydrochlorate of urea,	$CO(NH_2)_2HCl$;
Sulphate of urea,	$[CO(NH_2)_2]_2H_2SO_4$.

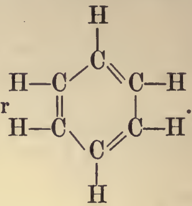
By replacing the oxygen in urea with sulphur, thioureas are formed. They are similar to urea in many respects.

What is carbamic acid?

If one hydroxyl of carbonic acid is replaced by amidogen, carbamic acid is produced. The free acid is not known. The salts are called carbamates; the esters, urethanes.

AROMATIC SERIES (C_nH_{2n-6}).

What are aromatic compounds?

The aromatic compounds are those which are mostly obtained from aromatic oils and resins. They differ in many respects from the fatty bodies, principally by having a greater number of carbon atoms. They contain at least six atoms of carbon, joined in the form of a ring (called the benzol ring). The lowest is benzene, C_6H_6 or  . The carbon atoms are joined by one and two bonds alternately.

Benzene and its derivatives, on account of special properties, are considered by themselves.

Mention some of the hydrocarbons C_nH_{2n-6} of the benzene series.

Benzene,	C_6H_6;	
Toluene,	$C_6H_5CH_3$,	methyl benzene;
Xylene,	$C_6H_4(CH_3)_2$,	dimethyl "
Cumene,	$C_6H_3(CH_3)_3$,	trimethyl "
Cymene,	$C_6H_4CH_3C_3H_7$,	methyl-propyl benzene.
C_nH_{2n-12},	naphthalene,	$C_{10}H_8$;
C_nH_{2n-18},	anthracene,	$C_{14}H_{10}$;
C_nH_{2n-4},	terpenes,	$C_{10}H_{16}$.

What are their properties?

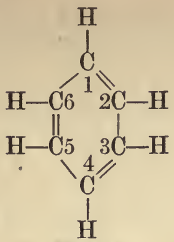
Benzene has unsaturated bonds, and is capable of forming "addition"-products, but, like the fatty bodies, the hydrogen atoms can be replaced by negative groups or elements, with the formation of substitution-products. Thus—

From benzol (benzene) are obtained :—

C_6H_5Cl,	benzene chloride;
$C_6H_5NO_2$,	nitrobenzene;
$C_6H_5NH_2$,	amidobenzene or aniline;
$C_6H_4Cl_2$,	dichlorbenzene (3 isomers possible).

Describe the isomerism of the benzene series.

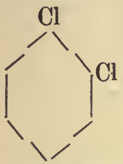
In the benzene series it can be proved that the hydrogen atoms are all equal, as only *one* mono derivative is known; but when two hydrogens are substituted, isomeric modifications arise, depending upon the relative position of the substituting elements or radicals. It is found that three different compounds can be obtained, depending whether the hydrogens substituted are on adjacent, alternate, or opposite carbon atoms:



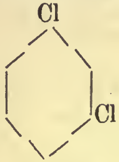
Benzene.

For convenience, the carbon atoms are numbered thus, each number referring to a certain position.

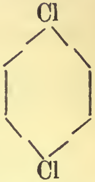
The isomeric di-derivatives are shown in the figures :—



1—2, dichlor benzene, called *ortho* dichlor benzene.



1—3, called *meta* dichlor benzene.

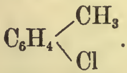


1—4, called *para* dichlor benzene.

These numbers and names will be used in this book instead of writing *hexagons.*

What are the homologues of benzene?

When the hydrogen atoms in benzene are replaced by fatty hydrocarbon radicals, the benzene homologues result. They yield two sorts of substitution-products, depending whether the substitution takes place in the ring or side chain :—

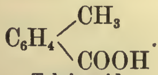


$$C_6H_4\begin{matrix}\diagup CH_3\\ \diagdown Cl\end{matrix}.$$

Chlor toluene.

$C_6H_5—CH_2—Cl.$

Benzyl chloride.



$$C_6H_4\begin{matrix}\diagup CH_3\\ \diagdown COOH\end{matrix}.$$

Toluic acid.

$C_6H_5—CH_2COOH.$

Phenyl acetic acid.

What are the properties of these compounds?

The aromatic compounds are very stable, the benzene ring being broken only with great difficulty. They are more readily crystallized and more reactive than the fatty group.

The union of substituting-groups is much stronger: thus chlorine is not removed by ammonia. The formation of nitro compounds is characteristic, and of sulpho acids by sulphuric acid.

They are more negative in their reactions than the fatty bodies. The hydroxyl derivatives (phenols) act like acids. The hydrogen of the hydroxyl can be replaced by metals (giving phenates) or by alkyls (giving phenolic ethers).

How are the aromatic hydrocarbons formed?

(1) Many are formed by the polymerization of fatty compounds caused by passing the latter through a red-hot tube:—

$$\underset{\text{Acetylene.}}{3C_2H_2} = \underset{\text{Benzene.}}{C_6H_6}. \qquad \underset{\text{Allylene.}}{3CH\equiv C-CH_3} = \underset{\substack{\text{Trimethyl}\\ \text{benzene.}}}{C_6H_3(CH_3)_3}.$$

By heating with sulphuric acid:—

$$\underset{\text{Crotonylene.}}{3CH_3-C\equiv C-CH_3} = \underset{\substack{\text{Hexamethyl}\\ \text{benzene.}}}{C_6(CH_3)_6}.$$

(2) By heating the acids with lime:—

$$\underset{\text{Benzoic acid.}}{C_6H_5CO_2H} + CaO = \underset{\text{Benzol.}}{C_6H_6} + CaCO_3.$$

(3) By heating the halogen derivatives with sodium:—

$$\underset{\text{Brom benzene.}}{C_6H_5Br} + \underset{\substack{\text{Methyl}\\ \text{bromide.}}}{CH_3Br} + Na_2 = \underset{\text{Toluene.}}{C_6H_5CH_3} + 2NaBr.$$

Many are obtained from coal-tar by fractional distillation.

How is benzene (C_6H_6) obtained?

Benzene is exclusively obtained from coal-tar by fractional distillation; but coal-tar benzol is never pure, and if pure benzene is to be obtained, method (2) for hydrocarbons must be used for its preparation.

What are its properties?

Benzene is a light, limpid, strongly refracting liquid with an ethereal odor. It boils at 80° C., is very inflammable, and its vapor forms an explosive mixture with air. It dissolves iodine, sulphur, phosphorus, fats, and other organic substances.

It forms substitution-products with ease, but is oxidized with difficulty. It forms addition-products:—

Benzol dichloride, $C_6H_6Cl_2$; Benzol hexachloride, $C_6H_6Cl_6$.

Mention some other hydrocarbons.

Toluene (methyl benzene),	$C_6H_5CH_3$, boiling-point 111° C.;
Xylene (dimethyl benzene),	$C_6H_5(CH_3)_2$, three isomers;
Mesitylene (trimethyl benzene),	$C_6H_3(CH_3)_3$, 1–3–5;

Pseudo-cumene (trimethyl benzene), $C_6H_3(CH_3)_3$, 1–3–4 or 1–2–4;
Cymene (methyl propyl benzene), $C_6H_4(CH_3)(C_3H_7)$, 1–4;
Durol (tetramethyl propyl benzene), $C_6H_2(CH_3)$, 1–2–4–5.

How are the halogen compounds formed?

(1) By the direct action of the halogens :—

$$C_6H_6 + Cl_2 = C_6H_5Cl + HCl;$$

(2) By the action of the halogen phosphorus compounds on hydroxyl derivatives :—

$$C_6H_5OH + PCl_5 = C_6H_5Cl + HCl + POCl_3.$$

What are their properties?

The halogen atom is very firmly united to carbon in these compounds, and cannot be easily replaced; if a nitro group be added, the halogen becomes more reactive.

How are the cyanogen derivatives formed?

By distilling the potassium salt of the sulpho acid with potassium cyanide :—

$$C_6H_5KSO_4 + KCN = C_6H_5CN + K_2SO_4.$$

What are their properties?

They are oils, with a smell like bitter almonds.

Benzyl cyanide, $C_6H_5CH_2CN$, occurs in the garden nasturtium and garden cress. Other cyanide derivatives have been prepared.

How are the nitro derivatives prepared?

By the action of nitric acid on the hydrocarbons :—

$$C_6H_6 + HNO_3 = C_6H_5NO_2 + H_2O.$$

This method is the only one used.

What are their properties?

They are generally yellow solids; some are liquids, insoluble in water, soluble in alcohol and ether. They are easily reduced to the amido compounds.

Nitrobenzene, $C_6H_5NO_2$, is used for making aniline. Other nitro derivatives are known :—

Trinitro chlor benzene (picryl chloride), $C_6H_2C(NO_2)_3$.

How are the amido derivatives prepared?

By the action of Zn or Sn and hydrochloric acid on the nitro compounds :—

$$C_6H_5NO_2 + Sn + 4HCl = C_6H_5NH_2 + SnCl_4 + H_2O + O.$$

If the benzene homologues are used, two sorts of compounds arise. If the substitution takes place in the side chain, compounds like fatty amines are formed; if in the benzene ring, true aromatic amines result. The first are like the fatty amines in their formations and properties. The second will now be considered.

$C_6H_4CH_3NH_2$;
Tolylamine.
Toluidine.

$C_6H_5CH_2NH_2$.
Phenyl methylamine.
Benzylamine.

The most important members of this group are aniline and the toluidines.

How is aniline prepared?

Aniline was first prepared by Unverdorben by distilling indigo. At present it is prepared by reducing nitrobenzol with iron and HCl. It can be obtained from "coal-tar," but not pure.

What are its properties?

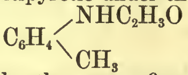
It is a colorless oil, heavier than water, in which it is slightly soluble. It forms soluble salts with acids. Nitro-, halogen-, and sulpho-acid derivatives are known. It is poisonous.

What are anilides?

If a hydrogen atom in amidogen is replaced by alkyl or acid (organic) radicals, compounds called anilides are formed thus:—

Methyl anilide, $C_6H_5NHCH_3$;
Ethyl anilide, $C_6H_5NHC_2H_5$;
Formanilide, C_6H_5NHCOH;
Acetanilide, $C_6H_5NHC_2H_3O_2$.

Acetanilide is used as an antipyretic under the name of antifebrine.

Ortho-methyl acetanilide, 

$C_6H_4\begin{cases}NHC_2H_3O\\CH_3\end{cases}$

(1–2), is also used as an antipyretic and antiseptic under the name of exalgine.

With nitrous acid, aniline (also other amido derivatives) gives first diazo compounds and then phenols.

Aniline is principally used for making aniline dyes; as aniline purple (mauve), aniline red or rosaniline, aniline violet (Hofmann's violet), aniline black, etc.

Mention some other amido derivatives.

o-Amido toluol or toluidine, $C_6H_4CH_3NH_2$ (1–2);
m-Amido toluol or toluidine, $C_6H_4CH_3NH_2$ (1–3);
p-Amido toluol or toluidine, $C_6H_4CH_3NH_2$ (1–4);
Amido xyloles or xylidenes, 6 isomers; etc., etc.

Diamido and triamido compounds are also known.

Phosphorus, arsenic, boron, silicon, and metallic derivatives of the aromatic compounds have been prepared.

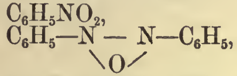
What are azo compounds?

The azo compounds consist of two atoms of nitrogen joined to each other by two bonds, the ends being joined directly to benzene rings. In diazo compounds only one of the nitrogen atoms is joined to a benzene ring, the other to some other radical (not benzene), thus:—

$$\underset{\text{Azobenzene.}}{C_6H_5—N=N—C_6H_5;} \qquad \underset{\text{Diazobenzene.}}{C_6H_5—N=N—OH.}$$

How are the azo compounds formed?

By the careful reduction of nitro compounds in alkaline solution, also by the oxidation of aniline. They are intermediate products between nitrobenzene and aniline, thus:—

$C_6H_5NO_2$,	Nitrobenzene;
 $C_6H_5—N — N—C_6H_5,\ \underset{\diagdown O \diagup}{}$	Azoxybenzene;
$C_6H_5—N=N—C_6H_5$,	Azobenzene;
$C_6H_5—NH—NH—C_6H_5$,	Hydrazobenzene;
$C_6H_5—NH_2$,	Aniline.

What are their properties?

The azo compounds are yellow or brown solids, insoluble in water, soluble in alcohol. By reduction they give hydrazo compounds. They are used for making the "azo colors."

How are the diazo compounds prepared?

By the action of nitrous acid on salts of the amido compounds:

$$C_6H_5NH_2HCl + HNO_2 = \underset{\text{Diazobenzene chloride.}}{C_6H_5—N=N—Cl} + 2H_2O.$$

If free aniline is used, diazoamido compounds result.

What are the properties of diazo compounds?

They are mostly colorless crystalline bodies, which turn brown in the air. They dissolve in water. When heated or struck they explode. Warmed with water they become phenols, with alcohol hydrocarbons. They are used for making dyes.

What are hydrazines?

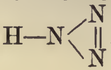
They are derivatives of hydrazine or diamide ($H_2=N—N=H_2$).

How are they prepared?

By the action of reducing agents on the diazo compounds:—

$$C_6H_5N=N—Cl + 2H_2 = C_6H_5—NH—N=H_2 + HCl.$$

What are their properties?

They form salts with acids. The free phenyl-hydrazine treated with nitrous acid yields a nitroso derivative; and if this is heated with dilute alkalies, phenyl-azo-imide is formed. The latter is the phenyl ether of hydrazoic acid, HN_3 or  $H{-}N{<}\begin{array}{c}N\\ \|\\ N\end{array}$, a very poisonous and explosive compound.

How are the sulpho derivatives formed?

By the action of sulphuric acid on the hydrocarbons:—

$$C_6H_6 + H_2SO_4 = C_6H_5HSO_3 + H_2O.$$

If sulphuric oxide is used, the sulphoxides are formed:—

$$2C_6H_6 + SO_3 = (C_6H_5)_2SO_2 + H_2O.$$

If chlor-sulphonic acid ($HClSO_3$) is used, sulpho-chlorides ($C_6H_5ClSO_3$) are formed, and these, reduced, give sulphinic acids ($C_6H_5HSO_3$).

What are the properties of the sulpho acids?

They are very stable compounds, not being decomposed by boiling alkalies. Fused with alkalies they yield phenols.

Mention some of the important derivatives.

Para-amido-benzen sulpho acid (sulphanilic acid), $C_6H_5NH_2HSO_3$, largely used for making dye-stuffs. Benzyl sulphanide (saccharine), $C_6H_4COSO_2NH$, a white substance, very sweet (280 times sweeter than sugar), used as an antiseptic and antiferment.

What are phenols?

They are hydrocarbons (aromatic) in which one or more hydrogen atoms have been replaced by hydroxyl:—

$$\underset{\text{Phenol.}}{C_6H_5OH}; \qquad \underset{\text{Cresol.}}{C_6H_4CH_3OH}; \qquad \underset{\text{Pyrocatechin.}}{C_6H_4(OH)_2\text{—}(1\text{–}2).}$$

In the homologues the hydroxyl may be on the ring or the side chain: the first are called phenols, the second aromatic alcohols. The latter are like the fatty alcohols in their formations and properties.

How are the phenols formed?

(1) By the action of nitrous acid on amido derivatives:—

$$C_6H_5NH_2 + HNO_2 = C_6H_5OH + N_2 + H_2O.$$

(2) By fusing the sulpho acids with caustic alkalies:—

$$C_6H_5HSO_3 + KOH = C_6H_5OH + KHSO_3.$$

Some of them are found in coal-tar as phenol, o + p cresols, etc.

What are their properties?

The phenols are more like acids than alcohols in their nature. They dissolve in alkalies, forming phenates ($C_6H_5O—M$). They also form ethers and other substitution-products.

How is phenol (C_6H_5OH) (called carbolic acid) prepared?

It may be prepared by any of the reactions already given, and it is often obtained from coal-tar by fractional distillation or solution with alkalies.

What are its properties?

It is a white crystalline substance which turns red in the air. It has a penetrating odor and burning taste. It is poisonous. It dissolves in water. A solution of impure phenol (called carbolic acid) is used as an antiseptic. A mixture of phenols (creasote) is used for preserving meat, wood, and other substances. It forms salts, ethers, nitro, and other derivatives.

Para acetamido ethyl phenol (phenacetin), $C_6H_4(O\overset{1}{C}_2H_5)(NH\overset{4}{C}_2H_3O)$, is used as an antipyretic. Trinitro-phenol (picric acid), $C_6H_2(\overset{(1)}{O}H(NO_2)_3$, 2–4–6, is a yellow substance; its salts are used as explosives.

What are the cresols, tolyl alcohols, $C_6H_4(OH)(CH_3)$?

They are methyl derivatives of phenol, $C_6H_4CH_3OH$. The ortho and para occur in coal-tar; the meta can be made by synthesis.

The most important derivatives are the propyl cresols, thymol, $C_6H_3\overset{1}{C}H_3—\overset{4}{C}_3H_7—\overset{3}{O}H$, and carvacrol, $C_6H_3\overset{1}{C}H_3—\overset{4}{C}_3H_7—\overset{2}{O}H$.

Thymol exists with cymene and thymene ($C_{10}H_{16}$) in oil of thyme. It is a crystalline substance with a mild odor and a peppery taste.

Carvacrol is contained in oil of caraway. It is a thick oil.

An iodine derivative of thymol (aristol) is used as an antiseptic; also tri iodo cresol (sosophane) and benzoyl cresol, $C_6H_4OCH_3CO_2C_6H_5$ (benzosol).

How are the diatomic phenols $C_nH^{2n-8}(OH)_2$ prepared?

By any of the general methods from the corresponding compounds. The principal ones are pyrocatechin, $C_6H_4(OH)_2$, 1–2; resorcin, $C_6H_4(OH)_5$, 1–3; hydrochinone, $C_6H_4(OH)_2$, 1–4.

Pyrocatechin, $C_6H_4(OH)_2$, 1–2, was first produced by the distillation of catechin. It is a crystalline compound, subliming without decomposition. Its monomethyl ether, $C_6H_4(OH)OCH_3)$, 1–2, guayacol, occurs in "beach tar," and is used as an antiseptic.

Resorcin, $C_6H_8(OH)_2$, 1–3. This may be obtained from asafœtida by fusion with alkalies. It is similar to pyrocatechin in many of its properties. If the oxygens are replaced by sulphur, a substance called thiol, $C_6H_4(SH)_2$, 1–3, is produced, which is used as an antiseptic.

Hydrochinone, $C_6H_4(OH)_2$, 1–4. This can be obtained from arbutin (a glucoside) by heating with dilute sulphuric acid. It is generally prepared by reducing quinone with sulphurous acid, $C_6H_4O_2 + H_2 = C_6H_4(OH)_2$. It is similar to the others in most of its properties. It is used as a reducing agent in photography.

What are quinones, $C_nH_{2n-8}O_2$, and how are they formed?

By the oxidation of various benzene derivatives as p-amidophenol, aniline, etc. *Quinone* is a yellow crystalline substance with a pungent odor. It is easily reduced to hydrochinone. Other quinones are known, and will be considered further on.

Of the triatomic phenols $C_6H_3(OH)_3$, which is the most important, and how is it obtained?

Pyrogallol (pyrogallic acid), $C_6H_3(OH)_3$, 1–2–3; obtained by heating gallic acid, also from its corresponding derivatives by heating with alkalies. It forms white crystals which sublime undecomposed. It is soluble in water. The alkaline solution absorbs oxygen from the air and becomes brown. It is used as a reducing agent.

Mention some of the phenol dyes.

Aurin (rosolic acid),	$C_{19}H_{16}O_4$;
Phenol phthlein,	$C_{20}H_{14}O_4$;
Resorcinol phthlein (fluorescein),	$C_{20}H_{12}O_5$;
Pyrogallol phthlein (gallein),	$C_{20}H_{14}O_8$.

What are the aromatic alcohols?

The aromatic alcohols have already been mentioned. They are like the fatty alcohols in their method of preparation and properties.

The most important are given in the following table:—

Benzyl alcohol,	$C_6H_5CH_2OH$;
Xylyl "	$C_6H_4(CH_3)—(CH_2OH)$;
Cymyl "	$C_9H_{11}CH_2OH$;
p-Xylene glycol,	$C_6H_4(CH_2OH)_2$;
Saliginin,	$C_6H_4OH—CH_2OH$;
Vanillic alcohol,	$C_6H_3(OCH_3,(OH)(CH_2OH)$;
Coniferyl "	$C_{10}H_{12}OH_3$;
Styryl "	C_9H_9OH;
Eugenol "	$C_{10}H_{10}(OH)_2$.

What are the aromatic aldehydes, and how are they formed?

They are like the fatty aldehydes in their formation and properties. The most important are the following:—

Mon-atomic	Benzaldehyde,	C_6H_5COH, ;
	Toluic aldehyde,	$C_6H_4(COH)(CH_3)$, three isomers ;
	Coninic aldehyde,	$C_6H_4(C_3H_7)(COH)$;
	o-Oxybenzaldehyde,	$C_6H_4(COH)(OH)$, salicylic aldehyde ;
	Protocatechuic aldehyde,	$C_6H_3(OH)_2COH$;
	Phthalic aldehyde,	$C_6H_4(COH)_2$;
	Cinnamic aldehyde,	$C_6H_5{-}CH = CH(COH)$, unsaturated. Oil of cinnamon.

How is benzaldehyde (C_6H_5COH) prepared?

By any of the ordinary methods for aldehydes. It is found as a glucoside in the oil of bitter almonds (called "oil of bitter almonds"). *The natural aldehyde always contains hydrocyanic acid.*

What are its properties?

It is a colorless oil with a characteristic smell, and soluble in water. It is easily oxidized to benzoic acid. It forms nitro, halogen, amido, and other derivatives. It is principally used for making benzoic acid and organic dye-stuffs.

Salicylic aldehyde, $C_6H_4(OH)(COH)$, 1–2 : this occurs in many flowers, as meadow-sweet, etc.

Anisic aldehyde, $C_6H_4(OCH_3)(COH)$, 1–2, occurs in oil of anise, etc.

Protocatechuic aldehyde, $C_6H_3(OH)_2(\overset{1}{C}OH)$, 1–3–4 : this is the basis of vanilla, piperonal, etc. It occurs in vanilla-beans, but can be prepared synthetically. The most important derivative is vanillin, $C_6H_3(COH)(OCH_3)OH$, the methyl ether. It is a crystalline substance with a well-known smell. Allied bodies are coniferin, $C_{16}H_{22}O_8$, and piperonal, $C_8H_6O_3$.

What are the aromatic ketones?

They may be of two kinds, *i. e.*, when both radicals are the same or when one radical is "fatty." They are similar to the fatty group in their formations and properties. A special method of formation is by the oxidation of methylene derivatives :—

$$(C_6H_5)_2CH_2 + O_2 = (C_6H_5)_2CO + H_2O.$$

The most important is phenyl methyl ketone (acetophenone), $CH_3COC_6H_5$, a light yellow liquid with a pleasant taste and smell. It has been used as a hypnotic under the name of hypnone.

Mention some other ketones.

Benzyl methyl ketone,	$C_6H_5CH_2{-}CO{-}CH_3$;
Diphenyl ketone (benzophenone),	$(C_6H_5)_2CO$;
Benzoin,	$C_6H_5CO{-}CHOHC_6H_5$;
Benzil,	$C_6H_5CO{-}COC_6H_5$.

How are the aromatic acids (monatomic) $C H_{2n-8}O_2$ formed?

(1) By reactions similar to those for the fatty acids;
(2) By the oxidation of benzene homologues:—

$$C_6H_5CH_3 + 3O = C_6H_5CO_2H + H_2O;$$

(3) By the action of CO_2 and sodium on the haloid ethers: —

$$C_6H_5Br + Na_2 + CO_2 = C_6H_5CO_2Na + NaBr.$$

These acids occur either free or combined in many resins and balsams and in the animal organism.

What are their properties?

They are similar to the fatty acids in most of their properties. They are solid, crystalline bodies. Most of them sublime without decomposition. They dissolve in water with difficulty. Heated with lime, they lose CO_2 and give hydrocarbons.

How is benzoic acid ($C_6H_5CO_2H$) formed?

This is the most important of the monatomic acids, and is found free in gum benzoin and combined (as hippuric acid) in the urine of herbivorous animals, in resins, and in "coal-tar." The common acid is purified by sublimation.

What are its properties?

It is a white, crystalline compound, slightly soluble in water. It sublimes unchanged. It forms salts, esters, and all the ordinary derivatives. It has been used (also some of its salts) as an antiseptic.

Its glycoll derivative, hippuric acid, $C_6H_5(CO)NHCH_2CO_2H$, occurs free, as already mentioned. It is a crystalline compound, scarcely soluble in water, but dissolves in alcohol. It forms salts and esters.

What is the principal monatomic acid (unsaturated)?

The most important acid is cinnamic acid (phenyl acrylic):—

$$C_6H_5—CH = CH—CO_2H.$$

How is it prepared?

It is prepared by the oxidation of oil of cinnamon (cinnamic aldehyde). It occurs with benzoic acid in Peru and Tolu balsams. It can be prepared synthetically by heating benzaldehyde with acetyl chloride:—

$$C_6H_5COH + CH_3COCl = (C_6H_5—CH = CHCO_2H) + HCl.$$

What are its properties?

It is a crystalline compound, soluble in hot water. It is without smell. It is easily oxidized, forming benzoic acid. It forms nitro, amido, and other derivatives, and, being unsaturated, forms "addition"-products.

What are the diatomic acids $C_nH_{2n-8}O_3$, and how are they prepared?

They are similar to the oxy-fatty acids. The most important is o-oxybenzoic (salicylic) acid.

How is it obtained?

It occurs in "meadow-sweet" and as the methyl ester in oil of "wintergreen," and it can be obtained by distilling the latter with caustic alkalies. It is made on a large scale by heating sodium phenate in a stream of CO_2 and decomposing the salt with H_2SO_4:—

$$2C_6H_5ONa + CO_2 = C_6H_4(CO_2Na)(ONa),\ 1\text{–}2,\ + C_6H_5OH.$$

What are its properties?

It is a crystalline compound, scarcely soluble in water, but dissolves in alcohol and ether. It forms salts, esters, and other derivatives. It forms an anhydride; *the meta and para acids do not.* This is true for all meta and para acids.

What are the other acids of this series?

Oxytoulic (cresotic) acid, $C_6H_3(CH_3)(OH)(CO_2H)$;
Amygdalic acid, $C_6H_5{-}CH(OH)(CO_2H)$.
(This acid occurs in amygdaline. It can be prepared synthetically.)
Hydrocoumaric acid, $C_6H_4(OH)(C_2H_4CO_2H)$;
Phenyl lactic acid, $C_6H_5{-}CH_2{-}CH(OH)(CO_2H)$.

What is tyrosine?

It is oxyphenyl-α-amido-propionic acid, $C_6H_4(OH)CHNH_2CO_2H$. It occurs in the liver, spleen, pancreatic gland, and old cheese. It can be prepared synthetically. It is a crystalline substance, scarcely soluble in water.

Mention some of the other acids of this series.

Coumaric (oxycinnamic) acid, $C_6H_4(OH)(CH{=}CHCO_2H)$;
Tropic acid, $C_6H_5{-}CH{=}(CH_2OH)(CO_2H)$, from atropine;
Protocatechuic (triatomic) acid, $C_6H_3(OH)_2(CO_2H)$, from catechin;
Caffeic acid, $C_6H_3(OH)_2(C_2H_2CO_2H)$, from caffetannic acid;
Piperic acid, $C_{12}H_{10}O_4$, from piperine.

What are the tetratomic acids $C_nH_{2n-8}O_5$?

They contain one more hydroxyl than the last.

The most important is gallic acid and tannic acid, $C_6H_2(OH)_3(CO_2H)$.

How is gallic acid obtained?

It occurs in nut-galls, sumach, tea, etc. It can be made by synthesis from di-iodo-salicylic acid.

What are its properties?

It is a crystalline compound, soluble in water and alcohol. Heated above 200° C., it is converted into pyrogallic acid. Its aqueous solution reduces the heavy metals. It is used in photography. It forms salts and esters.

What are tannins (tannic acids)?

These compounds constitute the astringent principles of plants. They are mostly glucosides of gallic acid. Many give black precipitates or colors with ferric salts (the common writing-inks). The tannins precipitate gelatine from its solution and combine with animal membranes, producing hard, insoluble substances (leather).

Mention the most important "tannin"?

Gallotannic acid ("tannin"), $C_{14}H_{10}O_9$.

How is it obtained?

It occurs in large quantities in "nut-galls," from which it is principally obtained. It can be made from gallic acid by heating with $SOCl_3$.

What are its properties?

It is a yellow, amorphous substance, very soluble in water, less so in alcohol and ether. It has an astringent, but not bitter, taste. It forms salts and esters.

Mention some of the other "tannins."

Quercitannic acid, from oak bark;
Catechutannic " " acacia catechu;
Caffetannic " " coffee-berries.

Mention some other acids of this series.

Quinnic acid, $C_7H_{12}O_6$, in cinchona bark;
Opianic acid, $C_{10}H_{10}O_5$, from narcotine.

What are the bibasic diatomic acids $C_nH_{2n-10}O_4$?

These acids contain two carboxyl groups, and can be formed by any of the general methods.

Phthalic acids, $C_6H_4(CO_2H)_2$. These are the most important members of this group. All three isomers are known, and are called ortho- (ordinary), meta-, and paraphthalic acid. The most important is ordinary or orthophthalic acid. It derives its name from naphthalene, from which it was first obtained.

How is phthalic acid prepared?

(1) By the oxidation of naphthalene:—

$$C_{10}H_8 + 4O_2 = C_8H_6O_4 + C_2H_2O_4.$$

It is generally prepared by heating naphthalene dichloride with nitric acid to a high temperature.

What are its properties?

It is a crystalline substance, soluble in water. It melts below 200° C., and if heated above, forms phthalic anhydride, $C_8H_4O_3$ (the meta and para acids do not form anhydrides). It forms acid and normal salts, esters, and other derivatives of the benzene series. It is used principally in the preparation of dye-stuffs.

Mention some of these dye-stuffs.

Phenol phthalein, $C_{20}H_{14}O_4$, is obtained by heating phenol with phthalic anhydride. It gives a red color with alkalies, and it is used as an indicator in alkalimetry.

Resorcinal phthalein (fluorescein), $C_{20}H_{12}O_5$, is obtained by heating resorcin with phthalic anhydride. Its solution is red, but has a bright green fluorescence, and a very small quantity of the substance can be recognized in water. Its halogen derivatives are used as pigments and dye-stuffs. They are called eosines.

Pyrogallol phthaline (galline) is prepared in the same way, only using pyrogallic acid. It gives a bright blue color with alkalies.

If the OH groups in the phenols are replaced by NH_2 groups, the rhodamines are formed, which give beautiful colors, and are used as dye-stuffs.

Mention some of the other acids of this series.

Tribasic benzo-tricarboxylic acid,	$C_6H_3(CO_2H)_3$;
Tetrabasic benzo-tetracarboxylic acid,	$C_6H_2(CO_2H)_4$;
Hexabasic benzo-hexacarboxylic acid,	$C_6(CO_2H)_6$.

The last is called mellitic acid and occurs in nature as the aluminium salt called mellite or honey-stone, from which it derives its name. It is found in beds of lignite.

What is indigo, and how is it obtained?

Indigo (C_8H_5NO) is the product of several species of plants of the genus indigofera. It does not exist free, but is produced by the decomposition of a glucoside (indican), $C_{26}H_{31}NO_{17}$, by boiling with acids or treating with a ferment. Commercial indigo is a mixture of several substances, indigo being the only useful constituent to the dyer. It is obtained by treating with various reagents to remove the other substances, and the indigo remains as a residue; or it may be purified by sublimation.

It can be made synthetically by melting brom-acet-anilid with caustic alkalies and oxidizing the aqueous solution by exposure to the air.

A substance similar to indican sometimes occurs in urine, giving rise by its conversion into indigo, to a blue color in the liquid when exposed to air.

What are the properties of indigo?

It is a dark blue substance with a coppery lustre. It has neither taste nor smell and is insoluble in water, alcohol, ether, alkalies, and dilute acids, but dissolves in strong sulphuric, forming a sulpho acid called sulphindigotic acid, a soluble compound used in dyeing. Reducing agents convert indigo into a colorless substance called "indigo white," $C_{16}H_{12}N_2O_2$, but it becomes blue (oxidized) again when exposed to the air. It is on this principle the dyer prepares his indigo vat. Indigo oxidized by chromic acid yields isotine, $C_6H_5NO_2$, and other allied bodies.

Mention some of the bodies allied to indigo?

Trioxindol,	$C_8H_7NO_3$;	Dioxindol,	$C_8H_7NO_2$;
Oxindol,	C_8H_7NO;	Indol,	C_8H_7N.

How is indol formed?

By the reduction of indigo or other similar bodies. It is formed by the putrefaction of albumenates, together with spatol or β-Methyl indol, $C_8H_5CH_3NH$. These substances occur in human feces and are the principal cause of its bad smell.

What are the compounds of the diphenyl group?

The compounds of this group contain two or more phenyl radicals joined together, or to other radicals.

How are they formed?

By passing the vapors of benzene or other compounds through red-hot tubes.

Diphenyl and some of its derivatives are found in "coal-tar," such as

Diphenylimide (carbazol),	$C_{12}H_9N$;
Acridine,	$C_{12}H_9N$;
Diphenyl methane,	$(C_6H_5)_2CH_2$;
Triphenyl methane,	$(C_6H_5)_3CH$.

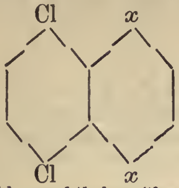
Some of them are used as the basis of the aniline dyes.

What is naphthalene, and how is it obtained?

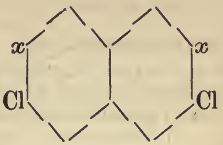
Naphthalene ($C_{10}H_8$) is produced by the decomposition of toluene, xylene, etc., at a red heat, or by passing the vapors of benzene, chrysene, etc., through a red-hot tube. It is found in large quantities in "coal-tar. It may be formed synthetically from phenyl butylene, $C_6H_5—CH_2—CH=CH—CH_3$.

What are its properties?

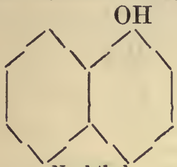
It forms large, colorless crystals with a faint peculiar odor. If strongly heated in the air, it takes fire. It is insoluble in water, but dissolves in alcohol and ether. Like benzene, it forms "substitution" and "addition" products; but two classes of compounds (α and β) are possible, depending upon the position of the substituting radicals, thus:—



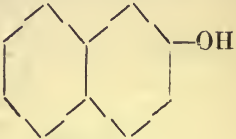
α-Dichlor naphthalene (these are called *alpha* derivatives).



β-Dichlor naphthalene (these are called *beta* derivatives).



α-Naphthol.



β-Naphthol.

The derivatives are produced by reactions perfectly analogous to those of the benzene derivatives.

Mention some of the important derivatives of naphthalene.

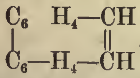
Amido naphthalenes (called naphthylamine), α and β, $C_{10}H_7NH_2$;
Naphthalene sulpho acids, α and β, $C_{10}H_7HSO_3$.
The sulpho acids of naphthylamine are called naphthionic acids.
The amido derivatives form salts, like aniline, etc. The salt of naphthylamine, together with sulphanilic acid, gives a red color with nitrates and nitrites, and this reaction is used as a test for these substances in water.

Other derivatives are:—

α and β naphthols, $C_{10}H_7OH$;
Naphthochinone, $C_{10}H_6O_2$;
Dinaphthyl, $C_{20}H_{14}$;
Naphthalene, $C_{10}H_8$, is used as an antiseptic;
Phenantherine and anthracene, $C_{14}H_{10}$.

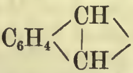
What are phenantherine and anthracene?

They are two isomeric compounds found in the portion of coal-tar which boils at over 300° C. They have the following formulæ:—



$$\begin{array}{l} C_6\ H_4-CH \\ | \qquad\quad \| \\ C_6-H_4-CH \end{array}$$

, phenantherine;



$$C_6H_4\left\langle \begin{array}{c} CH \\ | \\ CH \end{array} \right\rangle C_6H_4$$

, anthracene.

They form all the ordinary derivatives; only anthracene will be considered.

How is anthracene prepared?

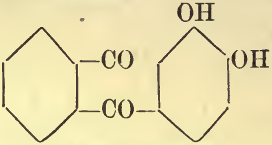
It can be prepared artificially by passing benzyl toluene, $C_6H_5CH_2—C_6H_4(CH_3)$, through a red-hot tube, but it is generally obtained from coal-tar.

What are its properties?

It is a colorless, crystalline compound, with a blue fluorescence, slightly soluble in alcohol and ether, but easily in benzene. It forms addition- and substitution-products. The most important compounds are the hydroxyl derivatives of anthrachinone, which are used as dye-stuffs.

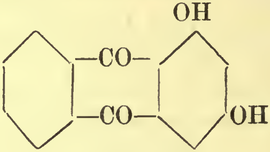
Mention some of their derivatives.

Alizarine,



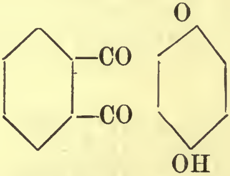
o-Dioxyanthrachinone.

Xanthopurpurin,



m-Dioxyanthrachinone.

Chinazin,



p-Dioxyanthrachinone.

What is alizarine, and how is it prepared?

It is found in nature, being the red coloring-matter of madder-root (rubia tinctorum), as a glucoside called ruberytheric acid. This, boiled with water, is resolved into glucose and alizarine :—

$$C_{26}H_{28}O_{14} + 2H_2O = C_{14}H_8O_4 + 2C_6H_{12}O_6.$$

This was the old method for obtaining alizarine, but at present it is exclusively obtained from anthracene, by fusing o-dibromanthrachinone with caustic alkalies, dissolving the fusion in water, and precipitating the alizarine with an acid. It is purified by crystallization and sublimation.

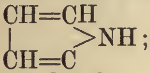
What are its properties?

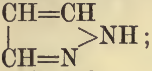
It is a yellow, crystalline substance, sparingly soluble in water, easily in alcohol and ether, also in sulphuric acid. It is like a diatomic phenol; has a weak acid reaction and dissolves in alkaline solutions with a purple color. Aluminium and tin form red precipitates, called madder lakes. Ferric salts give black precipitates. These are used in dyeing and calico-printing.

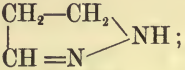
Other hydroxyl derivatives are used for the same purpose: they are purpurin trioxyanthrachinone, $C_{14}H_8O_5$; flavopurpurin, anthropurpurin, etc.

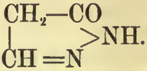
What are the pyrrol derivatives?

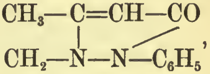
Pyrrol has already been mentioned, and its important derivatives are shown in the following formulæ :—


Pyrrol.


Pyrazol.

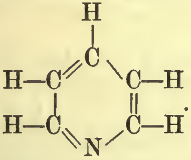

Pyrazolin.


Pyrazolon.

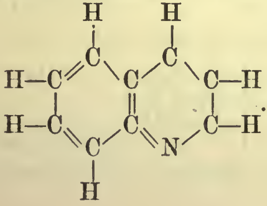
Phenyl-dimethyl-pyrazolon (antipyrine),  is a well-known substance which is used as an antipyretic.

What are the pyridines and chinolines?

Pyridine is benzene in which one carbon atom has been replaced by a nitrogen atom. Thus :—



Chinoline may be considered as naphthalene in which one carbon atom (α position) has been replaced by a nitrogen atom. Thus :—



There is also an isochinoline: N in the β position. These compounds, with many of their derivatives, are found in "coal-tar," "bone-oil," etc.

Mention some of the derivatives of pyridine.

Picoline (methyl pyridine),	$C_5H_4(CH_3)N$;
Lutidine (dimethyl pyridine),	$C_5H_3(CH_3)_2N$;
Collidine (trimethyl pyridine),	$C_5H_2(CH_3)_3N$.

These compounds are also formed by the distillation of various alkaloids. They can be made synthetically.

Hexahydropyridin (piperidin), $C_5H_{11}N$, is the active principle of pepper.

α-Normal-propyl piperidin (coneine), $C_8H_{17}N$, is the active principle of hemlock.

Hexahydrodipyridyl (nicotine), $C_{10}H_{14}N_2$, is another derivative of this group.

Mention some of the chinolin bases.

Chinolin,	C_9H_7N;
Lepidin (methyl chinolin),	$C_9H_6(CH_3)N$;
Cryptidin (dimethyl chinolin),	$C_9H_5(CH_3)_2N$;
Chinaldin (α-methyl chinolin),	$C_{10}H_9N$.

These compounds are found in bone-oil, or they can be obtained by distilling the alkaloids (chinin, cinchonin) with potash. Many of these compounds are used for making dye-stuffs.

Mention some of the important alkaloids.

Coneine, $C_8H_{17}N$, as has already been mentioned, exists in hemlock. It is very poisonous.

Nicotine, $C_{10}H_{14}N_2$, exists in the tobacco-plant; also very poisonous.

Opium bases: These occur in the juice of the poppy. They are:—

Morphine,	$C_{17}H_{19}NO_3$;
Codeine (methyl morphine),	$C_{18}H_{21}NO_3$;
Thebain,	$C_{19}H_{23}NO_3$;
Papaverine,	$C_{20}H_{21}NO_4$;
Narcotine,	$C_{22}H_{23}NO_7$;
Narceine,	$C_{23}H_{29}NO_9$.

Cinchona bases: These occur in cinchona bark, They are:—

Chinine,	$C_{20}H_{24}N_2O_2$ (quinine);
Cinchonine,	$C_{19}H_{22}N_2O$;
Conchinine,	$C_{20}H_{24}N_2O_2$;
Cinchonidine,	$C_{19}H_{22}N_2O$ (chinoidine or conchinine).

Quinine is the most important. It is a well-known drug, used extensively in fevers.

Strychnine bases: These are contained in nux vomica and St. Ignatius bean. They are very poisonous:—

Strychnine, $C_{21}H_{22}N_2O_2$; Brucine, $C_{23}H_{26}N_2O_4$.

Solanium bases: These bases occur in the solanium niger. They are: Atropine, hyoscyamine, and hyoscine, $C_{17}H_{23}NO_3$. They all have the same formula, but differ in other respects. They are used as mydriatics.

Cocaine, $C_{17}H_{21}NO_3$, is found in coca-leaves. It is used as a local anæsthetic.

Veratrine, $C_{32}H_{49}NO_9$, found in hellebore root.
Sinapin, $C_{16}H_{23}NO_5$, " " white mustard-seed.

What are terpenes?

The terpenes are volatile oils existing in plants, chiefly of the coniferous orders. They are related to the aromatic hydrocarbons from the fact that they yield cymene by distilling with iodine, and are converted into terephthalic acid by oxidation. They are dihydrocymenes, $C_{10}H_{16}$.

What is turpentine or oil of turpentine?

Turpentine oil, the most important member of this group, is contained in the wood, bark, and other parts of pines, firs, and similar trees. It is generally obtained by distilling the crude sap, alone or with water.

It was formerly supposed that all the volatile oils thus obtained having the formula $C_{10}H_{16}$ were identical; but recent investigations have shown that the turpentine oils obtained from different sources exhibit many differences in their chemical and physical properties, and that they are mixtures of isomeric hydrocarbons.

What are their properties?

The several varieties of turpentine oil, when purified, are colorless, mobile liquids, with a peculiar aromatic odor. They are insoluble in water, but are soluble in alcohol and ether. They dissolve iodine, sulphur, phosphorus, resins, etc. Solutions of the resins are called varnishes. They are used in medicine as stimulants. They are poisonous.

What are volatile or essential oils?

These oils are isomeric with turpentine, and are found in various plants and fruits, to which they communicate a characteristic smell or taste.

Lemon, oil of, from the rind of the fruit citrus limonum;
Sweet orange, oil of, from the rind of the fruit citrus aurantium;
Bergamot, oil of, from the citrus bergamia;
Neroli, oil of, from orange flowers;
Oil of caraway; oil of juniper; oil of laurel; oil of pepper; oil of lavender, etc.

What are camphors?

They are oxygenated compounds containing ten atoms of carbon, and closely related to the terpenes, with which they are associated, and appear to be formed by the oxidation of the latter.

Common (laurel or Japan) camphor, $C_{10}H_{16}O$, occurs in all parts of the camphor tree of China and Japan. It is obtained by distilling the woody parts with water and purifying the crude substance by sublimation.

What are its properties?

It is a colorless, transparent substance, with a strong, peculiar smell. Sparingly soluble in water, but more soluble in alcohol and ether. It sublimes without decomposition. It is used in medicine as a stimulant. also as an antiseptic. It is poisonous.

Mention some other camphors.

Borneol (Borneo camphor), $C_{10}H_{18}O$, is obtained from a tree growing in Borneo and Sumatra.

Menthol (mint camphor), $C_{10}H_{20}O$, occurs, together with a terpene, in oil of peppermint.

They are similar to ordinary camphor in their properties.

What are resins?

They appear to be mixtures of certain acids (called resin acids), and are produced by the oxidation of terpenes.

Mention some of the resins.

Colophonium, obtained as a residue from the distillation of turpentine. It is the common rosin.

Gum lac, from the East Indian fig trees.

When melted it forms shellac, which is used for making sealing-wax and varnish.

Amber, a fossil resin found associated with brown coal and lignite.

As gum-resins may be mentioned :—

Caoutchouc or India-rubber, gutta-percha, asafœtida, etc.

When caoutchouc is mixed with one-half its weight of sulphur and heated and pressed, it constitutes vulcanite or ebonite.

What are balsams?

They are natural mixtures of resins with volatile oils :—

Canada balsam, copaiba balsam, Peru balsam, tolu balsam, etc.

What are glucosides?

They are substances occurring in plants which are decomposed into glucose and other bodies by the action of acids or ferments.

Mention some of the important glucosides.

Æsculin, $C_{15}H_{16}O_9$, found in the bark of the horse-chestnut tree;

Arbutin, $C_{12}H_{16}O_7$, found in the leaves of the bear-berry tree;

Hesperidin, $C_{22}H_{26}O_{12}$, found in unripe fruit, like oranges, lemons, etc.

Quercitrin, $C_{36}H_{38}O_{20}$, found in quercitron bark (called old fustic);

Amygdaline, $C_{20}H_{27}NO_{11}$, exists in bitter almonds. It yields hydrocyanic acid as one of its decomposition-products;

Salicin, $C_{13}H_{18}O_7$, found in the leaves and young bark of willows.

What are bitter principles?

They are neutral bodies of an indefinite chemical character, and are therefore considered alone:—

Aloin,	$C_{17}H_{18}O_7$,	from aloes;
Cantharidin,	$C_{10}H_{12}O_4$,	found in Spanish flies;
Santonin,	$C_{15}H_{18}O_3$,	the active principle of worm-seeds;
Carotin,	$C_{18}H_{24}O$,	found in the cells of red carrot.

Mention some of the coloring-matters.

These substances give rise to the colors in plants, etc.:—

Carthamin,	$C_{14}H_{16}O_7$,	a red substance found in safflower;
Hæmatoxylin,	$C_{16}H_{14}O_6$,	“ “ “ “ logwood;
Brasiline,	$C_{16}H_{14}O_5$,	“ “ “ “ brazil-wood;
Curcumin,	$C_{14}H_{14}O_4$,	a yellow “ “ “ turmeric;
Carminic acid,	$C_{17}H_{18}O_{10}$,	a red “ “ “ cochineal;

Chlorophyll (?), leaf-green, the green color of plants.

What are gelatinous substances?

These are nitrogenous substances which yield gelatin when boiled with water, They are:—

Gelatin, bone-gelatin or gluten;
Chondrin, obtained from the cartilages;
Sincin, silk-gelatin, extracted from silk;
Fibroine, the chief constituent of silk.

What are "biliary" substances?

These are substances occurring in the bile, also in the blood, brain, and in some plants. They are:—

Glycocholic acid, $C_{26}H_{43}O_6N$, and taurocholic acid, $C_{26}H_{45}NSO_7$. These occur in bile as the sodium salts.

Cholesterin, $C_{26}H_{44}O$, a white, crystalline substance; and bile pigments —bilirubin and biliverdin.

What are albumenoids?

These substances, originally called proteids, form the principal constituent of the animal organism. They occur in plants (seeds), in which they are produced exclusively. The albumens exist in different varieties. Thus :—

Egg albumen, the principal part of the white of egg ;
Serum albumen occurs in the blood, lymph, etc. ;
Vegetable albumen occurs in nearly all vegetable juices ;
Fibrins : Blood fibrin separates from blood after it leaves the organism ;
Myosin constitutes the principal constituent of the muscles ;
Caseins : Milk casein occurs in the milk of all mammalia ;
Vegetable casein or legumin occurs chiefly in the seeds of leguminous plants ;
Hæmoglobin, in the blood ;
Lecithin, $C_{42}H_{86}NPO_9$, is found in the brain, nerves, and blood corpuscles.

PHYSICS.

HEAT.

What is heat?

Heat is a form of energy possessed by bodies probably in virtue of an irregular motion of their molecules. Its *effects* may be studied, but heat itself is imperfectly understood and can be defined only in a vague or theoretical way.

What are the theories of heat?

The *first* is the theory of emission, which holds that the molecules of bodies are surrounded by a subtle imponderable fluid, which can pass from one to another. These heat molecules cause repulsion of those of the substance and oppose cohesion.

The *second* is the undulatory theory. As with light, this demands existence of the ether, the molecules of which are in a state of vibration. These motions may be communicated to the molecules of bodies. The hottest bodies are those in which the movements have the greatest velocity and the greatest amplitude. According to this view, heat is a *condition* of matter and not a substance.

Which theory is generally accepted?

The undulatory theory, because it seems the more rational and because it explains the conditions which heat produces in a body.

Define temperature.

Temperature is the ability to give or to receive heat. Whenever a body gives heat to another it has a higher temperature, or is warmer; when it receives heat it has a lower temperature, or is colder.

What are the effects of heat?

The principal effects are:—

(1) To change the temperature of a substance;
(2) To convert solids to liquids, and liquids and solids to gases;
(3) To expand solids, liquids, and gases;
(4) To effect chemical decomposition;
(5) To hasten chemical union;
(6) To change color;
(7) To produce currents of air and water;
(8) To induce evaporation.

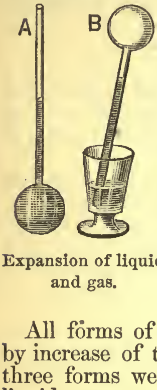
Illustrate the expansion of solids by heat.

Size is controlled by temperature. If we take a copper sphere and fit it accurately to a ring so that it just passes through when cold, and then raise its temperature, it fails to pass. It has swollen or undergone change by the action of heat. Cool it and it passes. Its size is, within certain limits, dependent on its temperature.

Demonstrate the expansion of liquids and gases.

Take a flask, *A*, Fig. 2, with a long neck, and place in it some colored alcohol, or any other fluid, mark on the neck its position, and then apply heat to the bulb. As the temperature augments the liquid rises in the neck, showing that it has undergone expansion. We also find that this is far greater than with the solid, when we were obliged to resort to the use of delicate means of measurement to demonstrate that there was an increase. Now remove the flame, contraction begins and, with return of the original temperature, the normal size is gained.

FIG. 2.



Expansion of liquid and gas.

Gases also follow this law, as illustrated by placing a flask, *B*, with the mouth of its neck under water, and adjusting, so that the level of the fluid is halfway up the stem and the rest filled with air. Apply a flame to the bulb: the merest touch suffices to cause an instant expansion of the included air, and if we are not careful some of it will escape from the vessel. With return to its former temperature the original size is gained.

All forms of matter, therefore, solid, liquid, and gas, are expanded by increase of temperature, and contract when it decreases. For the three forms we also learn that for solids the expansion is small, for liquids greater, and for gases the greatest of all.

What does "coefficient of expansion" mean?

It is the increase in size which a body assumes when heated from 0° to 1° C.

Do the three states of matter vary equally for a degree of heat?

No. Solids are least and gases most affected.

Do all solids expand at the same rate for the same increase of temperature?

Each solid has its own rate of increase and therefore its own individual coefficient of expansion, for which allowance must be made in various structures and combinations of solids.

Do all liquids have the same coefficient of expansion?

While the coefficients are numerically greater among liquids than among solids, their deviation is less, and no two liquids are known to have precisely the same coefficient.

At what rate do gases expand?

Owing to the freedom of molecular movement in gases their rates are so nearly alike that we can say a degree of heat augments any given volume of gas at 32° F. by $\frac{1}{491}$ of itself for every degree F. above that point.

Are there any exceptions to the law that heat expands?

Yes, among both solids and liquids. Water heated from 32° F. to 39° F. contracts, but expands by the application of more heat. Cast-iron. sulphur, and type-metal all expand at the point of solidification, and can therefore be used for making casts. Gold and lead, following the law of contraction, make imperfect casts, but give perfect outlines when stamped.

Give examples of decomposition by heat.

The constituents of some substances fly asunder with explosive violence when subjected to heat. Potassium chlorate is one of these compounds.

Discuss chemical union aided by heat.

Some substances unite readily at ordinary temperatures, others reluctantly, and others again are totally indifferent to each other until heat is applied; but union is almost invariably hastened by heat.

Cite examples of change of color by heat.

Color is largely dependent on temperature. Many fabrics have their color intensified by ironing. Many shades of red, blue, brown, etc., are very sensitive. The iodide of starch, prepared by adding a little tincture of iodine to a solution of starch, is of a rich dark blue hue; raise its temperature nearly to the boiling-point, and it becomes colorless. Cool it, and the blue tint is restored. So also red iodide of mercury sublimes yellow, white oxide of zinc heated turns yellow, and a host of other bodies, if submitted to a change of temperature, show change in color.

Thermometers.

What is a thermometer?

Any instrument used to determine temperature is termed a thermometer. Instruments depending on the expansion of gases, liquids, or solids may be employed. In general those with liquids are used.

What thermometers are ordinarily used?

The Fahrenheit and the Centigrade; the latter is coming into general favor, particularly for scientific observations.

How are thermometers made?

As usually constructed, these instruments consist of a glass bulb provided with a stem having a capillary tube. The bulb and a part of the stem are filled with a liquid, then heated to the boiling-point in order to expel the air. The open end of the tube is then sealed. The confined liquid indicates temperature by expansion or contraction. The scale of the thermometer is established by placing the bulb first in melting ice for the freezing-point, and secondly in boiling water for the boiling-point.

How does the Fahrenheit scale compare with the Centigrade?

	Freezing-point.	Boiling-point.	Difference of points.
Fahrenheit	32°	212°	180°
Centigrade	0°	100°	100°

1° Fahrenheit is therefore equal to $\frac{5}{9}$ of a degree Centigrade.

How may one of these scales be converted into the other?

The given Fahrenheit degrees, minus 32°, multiplied by $\frac{5}{9}$ will give the Centigrade temperature $(F. - 32) \times \frac{5}{9} = C.$

Centigrade degrees multiplied by $\frac{9}{5}$ then increased by 32° will give Fahrenheit degrees $(C. \times \frac{9}{5}) + 32^\circ = F.$

What liquids are used for thermometers?

Practically mercury and alcohol. The great advantage in the former is that it moves in a cleanly way in the tube, does not adhere to it or soil it, and gives very accurate indications. Its high boiling-point and low temperature required for solidification (a range from about 660° F. to nearly —40° F.), and its rapid movement, fit it admirably for this purpose.

When are alcoholic thermometers employed?

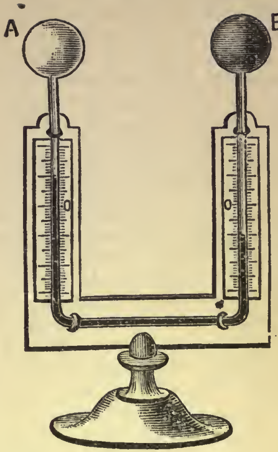
Where temperatures lower than —40° F. are to be measured, colored alcohol is employed. This boils at about 176° F., and does not solidify until —220° F. is reached; even at this point it can hardly be called solid. It soils or wets the wall of the tube; therefore, considorable time should be permitted for it to gain its true level when it has fallen before an exact reading can be made.

Describe the differential thermometer.

Take two bulbs, *A B*, and, having introduced some liquid into one, cement them together and bend the tube twice at right angles, to bring the bulbs opposite each other, Fig. 3. Now blacken *B* and we have a differential thermometer, or one which measures the difference in temperature between its bulbs. The slightest breath of warm air on *B* causes the index fluid to pass away from it towards *A*. A little cold water applied to *B* produces movement in the opposite direction. Place the instrument under an air-pump bell, and the liquid index is not affected by the most complete exhaustion. Though limited to determination of differences in the temperatures of its bulbs, it is most satisfactory and reliable when it can be employed.

Its chief use is to determine the temperature of neighboring points during experiments in physics.

Fig. 3.



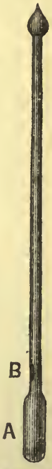
Differential thermometer.

Describe a medical thermometer.

In taking temperatures of the human body it is not required to register extremes of heat and cold. The recent demands of medicine have caused the construction of thermometers in which fractions of a degree can be easily indicated in the vicinity of 94° F., and the column of mercury *held at the point* to which it has risen. In these the bulb is made cylindrical, *A*, and the lower part of the tube contracted, *B*, Fig. 4. The movement of the fluid past this when expanding is not interfered with, but when contraction begins the column breaks and the thermometer indicates the highest temperature it has reached. When the instrument is used again the broken column is united by a slinging motion of the hand, bringing centrifugal force into play. The movement is repeated two or three times until the purpose is attained. For accuracy, such thermometers should be retained in their position for three to five minutes, to allow the mercury time to gain its true place.

These, and others which accompany urinometers, are often graduated only to 120°, or thereabouts. Care must be taken not to immerse them in liquids of a higher temperature, or they will be destroyed.

Fig. 4.



Medical thermometer.

Do thermometers measure the quantity of heat in a body?

They do not. If we take a series of vessels of increasing size and fill them with water from the same source, and then place a thermometer in each in succession, it marks the same degree. Yet we know that the largest vessel contains as much more heat than the smallest as its size is greater. From this we perceive that the thermometer does not measure the quantity of heat in a given mass. It merely *indicates the temperature intensity or the degree of heat.* The quantity is to be determined in other ways.

Given two substances of the same size and temperature, how does the same amount of heat affect them?

Besides increasing their volumes unequally it warms them unequally. If we take equal volumes of mercury and water and place them in front of a fire, the temperature of the former rises much more rapidly than that of the latter. If we use the same weights of the two substances, the difference is far more striking. From this we learn that *different bodies require different quantities of heat to warm them equally.*

In solids the same thing is evident. Take bullets of zinc and lead, and warm them equally by exposure to boiling water, giving them time to take up all the heat they will. Then drop them on a slab of wax about half an inch thick. The zinc melts its way through very quickly. The lead follows at a considerable interval. The heat held by the former was greater than that of the latter.

What is a thermal unit?

It is the quantity of heat required to increase the temperature of a pound of water one degree Centigrade.

What is specific heat?

By it we mean the amount of heat required to raise the temperature of a substance one degree compared with that required to raise the temperature of the same weight of water one degree.

If, therefore, it is stated that the specific heat of lead is 0.0314° C., it means that the quantity which would raise the temperature of a given weight of lead 1° C. would raise that of the same weight of water only 0.0314° C.

What is fusion?

It is the name applied to the transition of a body from a solid to a liquid condition. Substances like carbon, which do not fuse, are called *refractory.*

What are the laws of fusion?

1*st Law.*—A given solid begins to melt, with few exceptions easily explained, at a fixed temperature. This is called its point of fusion. It is a specific character of the substance. The range for solids is very great, as shown in the following table :—

	Centigrade.		Centigrade.
Carbonic acid	—78°	Tin	228°
Mercury	—40°	Lead	332°
Ice	0°	Silver	1000°
Phosphorus	44.2°	Gold	1200°
Wax	64°	Iron	1500°
Sulphur	115°	Platinum	2000°

2d Law.—During fusion the temperature of a body remains fixed; that of the fluid rises in spite of the most active stirring.

Solidification.—When a liquid is cooled it contracts and finally assumes the solid state, under the law that a liquid begins to solidify at the same degree at which the solid begins to melt. In other words, the solidification and the fusion-point are, as a rule, the same.

What is latent heat?

It is heat which does mechanical work by changing a solid to a liquid, or a liquid to a vapor, without changing the temperature. Water containing melted ice has a temperature of 0° C. No amount of heat will increase this temperature until the ice is melted. The heat utilized to melt the ice is termed latent or hidden, because it does not manifest its existence by producing warmth. Again, boiling water under ordinary conditions cannot be made hotter than 100° C. All superfluous heat becomes mechanical, transforming water into steam, and is called the latent heat of vaporization.

Can this latent heat be regained?

It can be recovered if suitable precautions are observed. A pound of steam, although no hotter than the boiling water from which it emanates, when condensed to a pound of water gives out an amount of heat equal to that required to convert the pound of water into steam. Ice melting absorbs heat, and the water thus produced, when frozen, again loses heat to the same amount as that previously absorbed.

How is latent heat measured?

The heat required to melt one pound of ice at 0° C. is the unit of measurement. It is 80 thermal units. This heat is sufficient to raise the temperature of one pound of water from 0° C. to 80° C. It is thus evident that one pound of ice at 0° C. mingled with one pound of water at 80° C. will, by its melting, cool the water to 0° C., and the mixture will become two pounds of water at 0° C. Two pounds of water at 40° C., or one and one-third pounds at 60° C., would perform the same work. A pound of water at 30° C. mixed with a pound of water at 10° C. renders an equalized temperature of 20° C. In this latter case no allowance is appropriated to change a solid to a liquid form.

What is the amount of heat in a pound of steam?

The heat necessary to raise the temperature of 537 pounds of water 1° C. suffices to evaporate one pound of water; therefore a pound of steam while condensing must liberate 537 Centigrade units, or enough to melt $6\frac{57}{80}$ pounds of ice at 0° C.

Is the freezing-point of water always 0° C.?

If water is kept perfectly still, the temperature may be carried considerably below 0° C. without the assumption of the solid state. If it is then touched, or the slightest agitation communicated to it, a portion instantly solidifies and the temperature rises to 0° C. Though it may be cooled below 0° C. without freezing, by no device can ice be warmed above that degree without melting. Melting of ice is therefore taken as the lower fixed point on the thermometric scale.

Under great pressure water retains its fluidity below 0° C. Broken ice may be compressed into lenticular, cylindrical, and other forms. This is what is known as regelation, a term introduced by Tyndall in explanation of the plastic nature of ice in glaciers.

What is a calorimeter?

It is an instrument for measuring the *quantity* of heat in a body. The *intensity* is measured by a thermometer. The simplest form consists of a block of ice having a cavity the mouth of which can be closed by a tightly fitting cover. The object whose heat is to be estimated is confined in the cavity, and the water which it produces by melting some of the ice gives data for calculations. More complex forms are used to determine the heat of fuel, etc. The object is confined in a vessel supplied with air-pipes to supply air, and burned in the vessel, which is surrounded by a known quantity of water at a known temperature. The increase of temperature furnishes the data.

What are freezing-mixtures?

They are fusions forced by the affinity between two substances. When ice is mixed with salt in the proportion of two parts of the former to one of the latter, the ice is rapidly melted, the rapid thaw involving a rapid disappearance of heat. If the mixture surrounds a liquid at the ordinary temperature, and if care is taken to prevent the ice from obtaining the necessary heat from other sources, the heat will be abstracted from the liquid, and in a short time its temperature will be so reduced that it will become frozen. The temperature obtained by the mixture of ice and salt, or snow and salt, is about zero Fahrenheit. Other freezing-mixtures are snow and crystallized chloride of calcium (3 to 4), nitrate of ammonium and water (equal parts), sulphate of soda and hydrochloric acid (8 to 5).

When is vaporization most rapid?

At the boiling-point, but it occurs at all temperatures, even ice emanating vapor. Evaporation depends on the temperature, pressure, extent of surface, and upon the amount of moisture already in the atmosphere.

Explain vaporization as a cooling process.

A liquid must absorb heat as a force to expel vapor. This heat it abstracts from adjacent matter, lowering its temperature. Sprinkling the floor cools the atmosphere of a room. Volatile substances applied to the temples reduce the surface temperature.

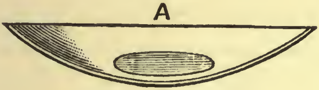
What medical application of this principle is made?

The cooling effect of vaporization is applied in surgery for the production of local anæsthesia. A fine spray of ether is directed upon the surface by means of an atomizer. By its rapid evaporation heat is abstracted from the part and intense cold produced, attended by loss of sensibility, and the knife can be used without causing pain. A similar arrangement is utilized for freezing soft tissues in making microscopic sections.

What is the spheroidal state?

If a metallic vessel, *A* (Fig. 5), is heated to a bright red and water thrown into it, instead of bursting into steam it quietly moves about on the surface, gathering itself up into a sphere, and gradually disappears. The assumption of this form is called the spheroidal state. Though seeming to be in contact with the metal, it is not, but floats about on a cushion of steam which bears it up. Rapid evaporation from its under surface doubtless has a cooling effect, and if we could examine the temperature of the mass it is not at all improbable that it would be found quite cool.

FIG. 5.



Spheroidal state.

If the metal is a thin platinum capsule and we remove it from the source of heat, the temperature declines, and when it reaches a point when the elasticity of the steam cushion is not sufficient to support the water, it falls on the hot surface and is almost instantly dissipated as steam.

What is crystallization?

There is a tendency to create geometric forms whenever a liquid passes to a solid. Any liquid would produce its special kind or kinds of crystals were it to cool with a certain regularity. The molecules require time to adjust themselves to the new conditions presented, and therefore the structure of a solid depends upon impeding or advancing this tendency even if crystals are not formed.

Define annealing.

The process of annealing consists in a gradual depression of temperature, and the allowance of a sufficient time for this adjustment to take place at least in a partial manner. Glass which has been suddenly chilled is exceedingly prone to fly in pieces if touched by a point or scratched; of this, the Prince Rupert drops are an example. The larger the mass the greater the difficulty in annealing it. The iron cylinders of great marine engines require weeks for the accomplishment of this process. In glass works it is an essential part of the manufacture, and the value of an article and its power to withstand rough usage depend entirely on the care with which it has been annealed. By recent devices, the so-called *malleable glass*, which will bear the roughest usage, is prepared. Pieces of it may be thrown violently on the floor without undergoing fracture.

What is sublimation?

A few substances like camphor and iodine pass directly from the solid to the gaseous form. This is termed sublimation.

How may the boiling-point of any liquid be changed?

By altering the forces opposing the escape of vapor. Changing the atmospheric pressure is important.

The ocean of air surrounding the earth and resting upon it by the influence of gravitation is rare above and denser as we descend. It follows that water boiled at a high elevation has but little air above to resist or hold vapor tending to escape. Therefore the water boils at a low temperature. At the earth's surface a longer column of air, consequently more weight, is sustained, and more heat energy is necessary to force away vapor rapidly. The boiling-point varies with the air pressure.

Explain the culinary paradox.

Dependent upon this fact is a curious phenomenon known as the culinary paradox, in which water is boiled by application of cold (Fig. 6). A flask, *A*, is half filled with boiling water, quickly corked, and placed bulb and neck in cold water, *B*. The liquid in the bulb at once begins to boil, and continues in that condition for some time. If, before it ceases, the cork is removed, there is a sudden inrush of air, showing that the interior was in a vacuous condition.

The explanation is simple: when the flask was placed in cold water the steam filling its upper part was condensed, and a vacuum was formed, in which the fluid boiled by virtue of the law just demonstrated that reduction of pressure is attended by lowering of boiling-point.

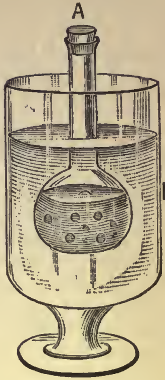
How is the variation of the boiling-point applied to arts?

Danger of burning attends the production of sugar. To obviate this difficulty the air is exhausted from a chamber above the syrup and boiling induced at a low degree. Foods *confined* in vessels are boiled at a temperature above 100° C.

How do substances in solution affect the boiling-point?

They make it higher. Substances dissolved in water tend to an elevation of the boiling-point, as follows :—

FIG. 6.



Culinary paradox.

Water boils at	100° C.
Water saturated with common salt boils at . .	109° C.
Water saturated with potassium nitrate boils at . .	116° C.
Water saturated with potassium carbonate boils at .	135° C.
Water saturated with calcium chloride boils at . .	179° C.

How do liquids compare in respect to the boiling-point?

The following table shows a wide variation :—

Ammonia,	—40° C. ;	Ether,	35° C. ;	Alcohol,	78° C. ;
Water,	100° C. ;	Mercury,	350° C. ;	Zinc,	1040° C.

What are the laws of ebullition?

(1) With any liquid boiling begins at a certain temperature which is constant for the same pressure ;

(2) The liquid maintains the same temperature during the process of boiling ;

(3) The boiling-point is raised by increased and lowered by decreased pressure.

Are the above laws absolutely true?

They deviate peculiarly. If water is boiled in a rough-iron pot, violent ebullition is produced at 211° F., a degree below the true boiling-point. If the surface is smooth, the temperature may rise to 214° F. before it is fairly established. This is the result of adhesion between the molecules of the vessel and those of the fluid.

Many liquids, as sulphuric acid, boil in a very irregular manner, the temperature rising a number of degrees above the true boiling-point. There is then a sudden violent rush of vapor, and the temperature falls to the standard, to rise again in the same manner. These irregular actions cease when some object which affords points for the escape of vapor are thrown into the vessel. In the preceding case, introduce a few pieces of platinum into the liquid and it boils in a quiet simmering.

Between what temperatures can life exist?

Life is possible between the temperatures which determine the fluid state of water. No living creature can survive a heat above 212° F., for the liquid constituents of the body would be dissipated. Certain low germs, however, retain their vitality. None but germs can bear a temperature below 32° F. It is true that a creature may in itself possess the power of generating heat and thus resist low temperatures, but remove this faculty, let the circulating juices of its body fall below 32° F., and, unless they are enclosed in capillaries, movement becomes impossible, and death supervenes.

How is evaporization applied to ice-making?

Some highly vaporizable liquid, as ether or ammonia, is caused to volatilize by diminution of pressure, accomplished by a pump. An intensely cold fluid is produced, which is used by some suitable device to abstract heat from the water to be frozen.

Describe Papin's digester and state its use.

It is a closed boiler in which water is heated under pressure and its boiling-point raised. With this rise it gains increased power of solution over all kinds of animal and other substances. Tendons, cartilage, and other gelatinous bodies placed therein under a pressure of four or five atmospheres are quickly dissolved. In this manner albumenoid substances are extracted from bones.

DISTILLATION.

What is distillation?

It is dissociating liquids from compounds by evaporation and condensation. It is based on the fact that the liquid whose boiling-point is lowest evaporates more rapidly than those with which it is associated. The mixture is heated in a vessel called the still. It should not boil, but only simmer gently. The formation of spray and carrying over of minute portions are thus avoided, and a purer distillate obtained. As vapor arises in the still it is received in the worm, which is a tube coiled spirally and immersed in cold water. In this the steam is condensed and escapes below in a fluid state.

As a rule, the first fifth and the last two-fifths of a specimen are not collected. The first contains vapors which are objectionable; the last two, salts in increasing quantity, and the liability to the formation of spray and destruction of the whole distillate is very great.

It is an excellent practice to follow a species of fractional distillation, collecting the distillate by tenths and mingling those which are pure.

ATMOSPHERIC MOISTURE.

What is atmospheric humidity?

The atmosphere always contains water-vapor, but is "*saturated*" only when it cannot receive more moisture from bodies with which it is in contact. The weight of this moisture in a moist volume of air is called its *humidity.*

What is fog?

A wave of cold air meeting a humid current cools and condenses its moisture into a visible form termed fog.

What is rain?

It is produced by the condensation of fog vesicles in the clouds or by the coalescence of minute drops, until at last those of greater and greater size are attained, and rain begins to fall.

What is dew?

By condensing the humidity of the air, materials which cool quickly at night accumulate moisture on their surfaces. Dew does not fall. Objects whose retained heat makes them warmer than the air receive no dew.

The dew-point is the temperature at which dew is formed.

Moisture on an ice-pitcher is an illustration of this principle.

SOURCES OF HEAT.

Mention the sources of heat.

(1) *The sun*, the origin of whose heat is a subject of conjecture.

(2) *Combustion:* A burning body and a decaying body of the same size and material emit the same total of heat, although its *intensity* for a unit of time varies.

(3) *Mechanical action*, as friction of all kinds. By blows or percussion a blacksmith may make a small portion of iron red-hot. A bullet discharged against an iron target melts by the sudden arrest of its movement. The savage creates fire by rubbing two sticks together. Indeed, heat is the final form of energy to which all other forms tend and in which they will all be finally dissipated.

(4) *Chemical action:* Heat may be evoked by the admixture of liquids, such as cold water and sulphuric acid.

(5) *Electric action*, occurring when resistance is offered to an electric

current: a principle which has recently been utilized in the incandescent carbon or platinum light of Edison.

(6) *Animal heat:* That division of the animal kingdom known as the warm-blooded create and dispense large quantities of heat. Considering the animal body to be a complex laboratory in which chemical changes are many and oxidation salient, we may account for its temperature. The blood appropriates parts of the food and is oxidized by the inhaled air. Representatives of the animal kingdom requiring but little air, therefore having sluggish oxidation, are termed cold-blooded.

(7) *Vegetable heat:* Plants emit heat, particularly when their energy is concentrated at the flowering season. The chemical processes taking effect within the plant transform earthy matter and gases into starch, sugar, and other products.

DIFFUSION OF HEAT.

By what methods is heat diffused?

It is communicated by conduction, convection, and radiation.

Explain heating by conduction.

It is when heat passes, molecule by molecule, from the warmer to the cooler parts of a body, as when the end of a metal rod is held in a flame and heat traverses to the opposite extremity.

Is the conductivity of all substances the same?

No. Heat passes rapidly through metals and slowly through wool, hair, etc. Hence we have good conductors and non-conductors. For this reason the sense of touch is differently impressed by the heat of different articles having the same temperature. Woollen fabrics, however cold, do not feel uncomfortable, because they do not absorb heat rapidly; but linen and metal, although at a higher temperature may seem cold.

Compare the conductivity of a few metals.

Silver and copper are the best conductors:—

Silver, 100;	Copper, 74;	Gold, 53.;
Steel, 12;	Platinum, 8;	Bismuth, 2.

Explain the principle of conduction as applied to clothing.

(1) Clothing to retain heat should be of non-conducting fabric, such as woollen and silk. Linen and cotton being good conductors aid the escape of heat and are called "cool."

(2) The body may be protected from extreme heat by interposing non-conducting material, as a shield. This fact when utilized permits firemen to work near furnaces and molten metal.

What is the method of heating by convection?

This method is applied to heating gases and liquids. When the heat is applied from below the heated particles rise and give place to the colder particles, which descend and in turn become heated. In this manner a circulation is established and is continued until the entire mass is equalized in temperature. The atmosphere is heated chiefly by convection. The air in contact with the warm earth rises, thus creating a current. For economy all liquids are heated from below. A vessel of water heated from above is but slowly heated for the reason that the warmed surface water is rarer than the lower portions, and therefore remains at the surface. Convection does not take place, and the mass, if heated, must be heated by conduction. Water, however, is a poor conductor of heat, and this process would be so extremely slow that the surface water would boil before the temperature of the lower portion could be much changed.

Describe an anemometer.

Heated air rising from the earth and moving laterally produces currents which when forcible are termed winds. These are the result of atmospheric convection, and their force is measured by the anemometer. This instrument has four hollow hemispheres set at the extremities of two diameters (at right angles) of a circle. These cups rotating by the wind register their velocity by means of attached clock-work. The centre of each cup moves with a rapidity equal to one-third of that of the wind.

Explain radiation.

Heat which one body receives from another through space is radiant heat. If we stand in front of a brightly burning fire, we feel the impression of heat upon the face and other parts of the body exposed to its action. If a book or other opaque object is interposed between the face and the source of heat, it is completely cut off. Remove it, and again warmth is experienced. From this we learn that heat from a fire moves in straight lines like the radii of a sphere. Hence it is called radiant, because it escapes from the body equally in all directions as radii. This effect, moreover, is as well marked in vacuo as in air. Heat, like light, is the resultant of vibrations in the ether.

Do all bodies radiate heat with the same freedom?

They do not. Some substances are as reluctant to surrender their heat as others are free to yield theirs.

In general, what objects are good radiators?

Bodies whose superficial condition enables them to radiate heat well, also absorb it well. A rough black substance is, therefore, a good absorber as well as radiator. Such bodies are bad reflectors, while good reflectors are bad radiators. An application of this is offered by an ordinary polished teapot. Its brilliant surface enables it to retain the temperature of the fluid for a long time, the higher the polish the better it acts in this respect.

Of all substances lampblack is the best absorbent of heat, its index standing higher than that of any other body.

Define luminous heat and obscure heat.

The luminous species comes from luminous bodies; obscure heat emanates from bodies heated below the degree of redness. The former, although separable, tends to accompany light.

Can the obscure rays be separated from the luminous?

They can. Iodine dissolved in carbon disulphide transmits the obscure and absorbs the luminous rays.

While light passes through all clear or transparent bodies with but slight loss dependent upon their color and degree of opacity, it is not so with radiant heat. A sheet of perfectly clear glass is quite transparent or *diathermous* to the heat emitted from a red-hot cannon-ball, but opaque or *athermous* to that given off by a boiling tea-kettle. Mica, rock-salt, and certain other substances bear the same relation to heat that glass bears to light; that is, they transmit it with perfect facility whether it comes from a body with a high or low temperature, though they may not in themselves be perfectly clear to light. Indeed, a black mica almost opaque to light transmits radiant heat of low intensity with great freedom.

How can light and heat rays be separated?

If the beam from an electric lamp be passed through a cell of alum solution, its heat rays will, to a very large extent, be sifted out, while the light rays will be permitted to pass; a cell of bisulphide of carbon will intercept neither.

How are heat and work associated?

In considering the relation between work and heat it is necessary to understand how much heat a given amount of work will produce, and *vice versa*. A pound ball falling 1390 feet generates, when stopped suddenly, sufficient heat to raise one pound of water 1° C. This is called Joules' equivalent, and means that the heat which will increase the temperature of one pound of water 1° C. is force equivalent to that exerted by a machine raising 1390 pounds one foot, or one pound 1390 feet.

Heat and work are interconvertible.

What are some of the applications of heat to produce work?

If we take advantage of the fact that heat causes expansion in and converts solids to liquids and liquids to vapor, there are innumerable opportunities to utilize it as a power to do work and economize manual labor. Heat abundantly applied to water produces steam, which by its elastic force when confined can be made to move pistons, which in turn give motion to intricate machinery capable of doing work. The steam-engine is perhaps the most important application of heat-work.

What are the kinds of steam-engines?

There are two kinds of steam-engines, known as the *condensing* and the *non-condensing engine.* The steam of the former lifts the piston, and instead of finding an exit to the atmosphere, which would resist its egress at a rate of fifteen pounds per square inch, it is conducted to a condensing chamber, from which, after being condensed, it is pumped back to the boiler. This last process creates a partial vacuum and therefore lessens the pressure which the utilized steam must resist. The non-condensing engine does not condense its steam, but allows it to escape against the atmospheric pressure.

The condensing engines are in general the more economical. Formerly engines were termed *low* and *high* pressure engines.

Gas, air, and naphtha are frequently used in engines when space and light work are to be considered.

LIGHT.

Define light.

Light is that form of motion or energy capable of affecting the nervous portion of the eye and producing vision.

What are the two accepted theories of light?

(1) The emission or corpuscular theory;
(2) The undulatory theory.

Explain the emission theory.

The *emission theory* assumes that luminous bodies throw off particles or molecules with inconceivable velocity in straight lines, and that these falling upon the retina or sensitive nervous coat of the eye produce the impression of light. In view of recent ideas regarding "radiant" or "ultra-gaseous" matter, it has been suggested that the corpuscular theory may be true, at least for the propagation of light through space, while the undulatory theory is correct as regards the relation of this form of energy to atmospheric and other transparent terrestrial media.

What is the undulatory theory?

According to this theory, all space, both inter-molecular and inter-stellar, is filled by an exceedingly attenuated medium, to which the name of *the luminiferous ether* is given. As sound comes to us by vibration or waves in the atmosphere, *so light results from an inconceivably rapid vibration of the molecules of the luminous body; these vibrations, moreover, are transmitted through the luminiferous ether as wave-like movements, and falling upon the retina cause the sensation of light.*

What other theory has been discussed?

An electro-magnetic theory of light has been brought forward by James Clark Maxwell. The main proof of this theory lies in the fact that the rate at which an electro-magnetic wave disturbance would travel may be calculated from electrical measurements. The rate at which light travels has been determined within very narrow limits of error. The two velocities are almost identical. Maxwell's generalizations on this subject were founded on Faraday's experiments showing that powerful magnets could rotate a beam of polarized light.

Why has the undulatory theory been given preference?

It was shown by Young and Fresnel that by means of the undulatory theory many phenomena of diffraction and polarization might be explained; this led finally to its general adoption.

What is the relation between heat and light?

Their difference is supposed to depend upon wave-lengths. Each is supposed to be the result of wave-motion, the length and rapidity of which determine the intensity. Substances accumulating heat approach a light-giving point, and it is probable that a more sensitively created eye could detect light at lower temperatures than the normal eye. Luminous vibrations are transverse.

Define transparent, translucent, and opaque bodies.

(1) *Transparent bodies*—thin glass, clear water, etc.—are those which transmit all or nearly all the light they receive. Objects viewed through them are well defined.

(2) *Translucent bodies*—ground-glass, colored water, etc.—transmit but part of the light which falls upon them. Objects seen through them are indistinct.

(3) *Opaque bodies*—such as masses of wood, rock, metal, etc.—intercept all light and transmit none.

How is light propagated?

Always in straight lines through any homogeneous medium. Light admitted through a small aperture into a dark room takes a straight course, as revealed by the visible dust particles.

What are the sources of light?

The celestial sources are the sun, stars, comets, shooting stars, lightning, and the aurora borealis.

The terrestrial sources are combustion, electricity, phosphorescence.

What is phosphorescence?

It is the power which many bodies possess of emitting light under certain stimuli. It is attended with little or no heat, and may be the result of slow oxidization, of nervous action, heat, electricity, or exposure to the sun. Examples are seen in decaying wood; the fire-fly; bits of sugar rubbed together in the dark; in certain chemicals when exposed to strong sunlight and afterwards placed in the dark. Calcium sulphide is such a chemical.

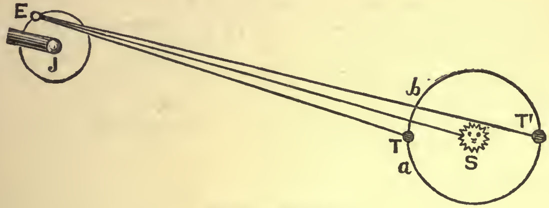
What is the velocity of light?

In space, light travels with a velocity of about 188,000 miles per second. In water it is about three-fourths as much; and, in general, the denser the medium the slower the rate.

How was this velocity first determined?

The first determination of the velocity of light was made by Roemer, a Danish astronomer, in 1675. The method employed was by the observation of Jupiter's satellites. The first satellite, *E* (Fig. 7), is occulted or passes behind the planet *J* at equal periods of about forty-two and a half hours. When the earth passes from *a* to *b*, on the side of its orbit nearest to Jupiter, there is but little difference in its distance from day to day, and, therefore, but little variation between two occultations. When, on the contrary, the earth in its revolution around the sun passes from *T* to *T′* on the opposite side of its orbit, it is found that there has been a total retardation of the actual from the calculated time of occultation of about sixteen and a half minutes. This represents the time required for the light to pass from one to the other side of the earth's orbit. Taking the earth's distance from the sun at 95,000,000 miles, Roemer computed the velocity of light at 190,000 miles per second. At the modern estimate of 91,500,000 miles for the sun's distance from the earth, the rate is 185,000 miles per second.

FIG. 7.



Velocity of light.

What was Fizeau's experiment?

Fizeau's method consists in placing a plane mirror directly in front of a source of light, but at a great distance from it. An observer, stationed behind the light, perceives the beam reflected from the mirror, that is, after it has travelled from the light to the mirror and back again. In front of the source of light is a toothed wheel capable of being revolved with a varying degree of rapidity. The wheel may be turned at such a rate that a beam of light travelling from the source may pass in the space between two teeth and be reflected in time to be intercepted by a tooth, so that the light will be invisible. Thus, from the rapidity of the wheel's revolution, and the number of teeth, the time occupied by the light in travelling to the mirror and back again can be estimated, and, the distance being known, the velocity of light can be calculated. The velocity is said to be 186,000 miles per second, or seven and a half times round the earth per second.

Explain the phenomenon of "seeing an object."

Every point of a luminous body gives out rays in every direction. The eye receives a cone of light the vertex of which is the point of "most distinct vision" on the retina and the pupil of the eye the base. Of the many individuals viewing the same object, no two recognize it by the same cone of light.

What are the laws of intensity of light?

The intensity of light perpendicular to an object is inversely proportional to the square of the distance from the source of light. A book held two feet from a lamp, then removed five feet from it, will in the last position receive but four twenty-fifths as much light.

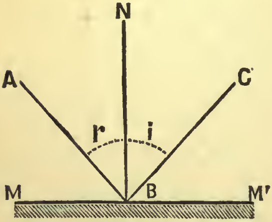
Light falling obliquely is dependent for its intensity upon the angle of obliquity and also upon the distance.

Define reflected light.

Highly polished surfaces intercept rays of light and cause them to glance or change direction. Light thus diverted is termed reflected light.

What are the laws of reflected light?

FIG. 8.



Reflection.

In the case of a perfectly burnished regular or specular surface, the laws for reflection of light are the same as for reflection of motion, viz. :—

1st. *The reflected ray A B, Fig. 8, is in the plane determined by the incident ray C B and a normal or perpendicular, N, drawn to the reflecting surface M M′ at the point of incidence.*

2d. *The angle* r *made by the reflected ray with the normal (angle of reflection) is equal to the angle* i *which the incident ray makes with the same normal (angle of incidence).*

A perfectly polished surface, if it could be made, would be invisible.

How do unpolished surfaces affect light?

They diffuse or scatter it. The projecting particles of a rough surface correspond to minute mirrors more or less perfect, whose planes, facing in many directions, reflect the light accordingly, instead of reflecting it from a single plane.

What are the kinds of mirrors?

As any polished surface is a mirror, we may have three kinds, viz., plane, concave, and convex. The two latter may be portions of the surface of a sphere, one reflecting from the interior, the other from the exterior.

Discuss a spherical concave mirror.

A line joining the centre of the mirror and the centre of the sphere of which it is part, and produced to any length, is the principal axis; the radius of the sphere is the radius of curvature.

How are the images of plane mirrors formed?

The effect of a plane mirror, as is well known, is to produce behind it images which accurately represent in size and form the objects in front. This result may be explained according to the laws of reflection.

In Fig. 9 a divergent pencil of light proceeds from a luminous point at the top of a candle-flame, *A*, and is reflected from the mirror at *B*. After reflection the rays on entering the eye have the same divergence as when they impinged upon the mirror, and if produced backwards meet at a point, *C*, which is the position of the image of the top of the flame. In like manner, every point appears in its proper position, and a complete image is observed.

The images produced by plane mirrors are *erect images*, but they are not exact duplicates of the objects, since they differ from them exactly as the right hand differs from the left. This may be readily seen if we examine the reflected image of a page of print in a mirror, when it appears as if viewed through the back of the page, or like the surface of the type from which it was printed.

FIG. 9.

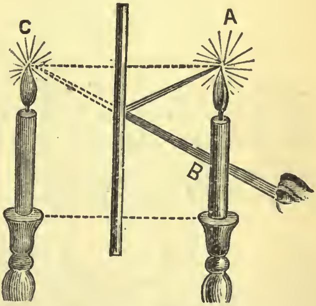
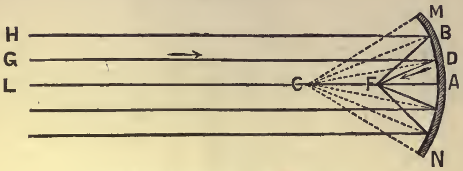


Image in plane mirror.

Considering the concave surface to be made of an infinite number of small plane mirrors, each of which receives a ray of light *parallel* to the principal axis and reflects it according to known laws, it is possible to conceive all the rays reflected to a common point called the principal *focus*. Its distance from the mirror is one-half the radius.

A light placed at the principal focus sends to each mirror rays which are reflected parallel to the principal axis. The rays *HB*, *GD*, etc. (Fig. 10), are parallel to the axis *LA*, and are reflected to meet at the point *F*. Conversely, rays from the point *F* are reflected in parallel lines, *BH*, *DG*, etc.

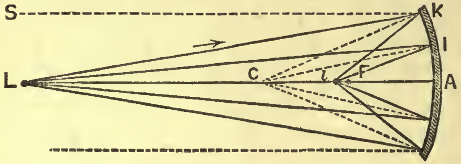
FIG. 10.



Focus of spherical concave mirror.

If, in Fig. 11, a luminous point is placed at *l*, between the centre of curvature and the principal focus, its rays will be reflected to the focus *L*; and, in reverse, a light at *L* will be reflected to the focus *l*. These points are called the conjugate foci.

FIG. 11.

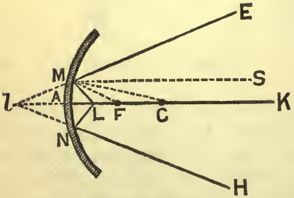


Conjugate foci.

Define real and virtual foci.

When the source of light and the focus of its rays are on the same side of the mirror, the focus is real. When they are on opposite sides, the focus is virtual. In Fig. 12, the luminous point *L* is so near the mirror that its reflected rays do not meet unless we imagine them prolonged beyond the mirror to the point *l*. The focus is therefore virtual.

FIG. 12.



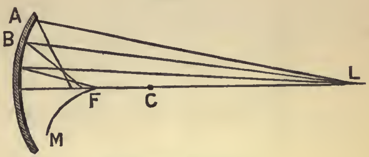
Virtual focus.

A small screen of white paper placed in the focus of parallel rays will receive an image of their luminous source, or if placed in one of the conjugate foci will receive an image of the light at the other.

Do spherical mirrors of any size conform to the same laws?

For arcs of more than ten degrees there are deviations: if the exterior rays reach a focus nearer to the mirror than those reflected from the regions about the pole, as at B, the image is blurred. To this effect and its cause the term *spherical aberration* is applied. It is represented (Fig. 13) where the ray from L, reflected from A, cuts the principal axis within the point at which the ray reflected from B reaches it. By connecting the point of intersection, the curve MF is obtained. This is called the *caustic*. It is perceivable when lamp-light or candle-light is reflected from the interior of a tumbler upon milk or other fluid contained therein.

FIG. 13.

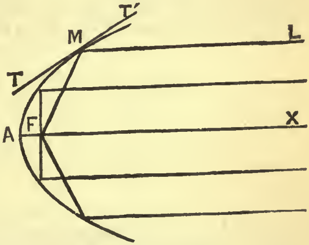


Spherical aberration.

How is spherical aberration overcome?

By using the curve of a parabola instead of that of a sphere. Fig. 14 indicates that in a parabola any straight line, FM, drawn from the focus to any point, M, and there meeting a line, ML, parallel to the axis, will form equal angles with a tangent, TT', to the curve at their point of intersection, M. From this it follows that all rays parallel to the axis will be reflected to the focus; and, conversely, a luminous point at the focus will give parallel rays. Hence the use of these in railway and carriage reflectors.

FIG. 14.

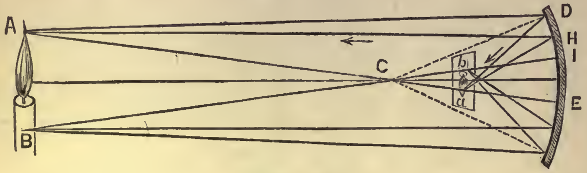


Parabolic mirror.

What are the images of concave mirrors?

Their images, like their foci, are real or virtual. An image is a series of points; a focus but one point (Fig. 15). Similarly, conjugate foci of all points between A and B will be formed between a and b, and thus between a and b an image of AB will be formed. The image is in front of the mirror, it is upside down, and is smaller than AB. Thus *in concave mirrors, where the object is beyond the centre of curvature, an image will be formed between the centre of curvature and the principal focus, and the image is real, inverted, and smaller than the object.* Suppose the object were at an infinite distance, the image would be at the principal focus. As the object approaches the centre of curvature, the image moves outwards from the principal focus towards the centre. If the object were at the centre, the image would coincide with it.

FIG. 15.



Real image.

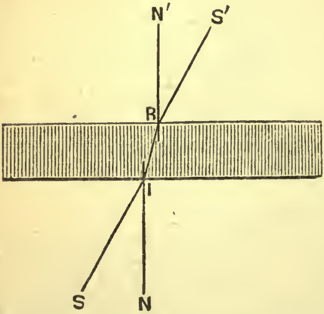
What are the images of convex mirrors?

They are always virtual and erect; smaller than the object.

What is refraction of light?

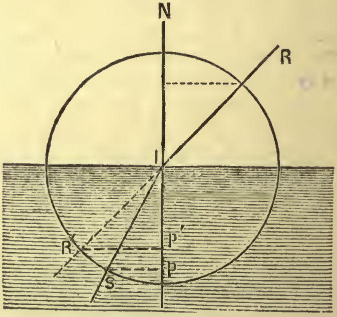
It is the change of direction which light undergoes when passing through different media. If a ray of light strike parallel surfaces perpendicularly, there is no deviation in its direction. Its course is a straight line, and there is no refraction. In Fig. 16, the ray $S'R$ takes the direction RI and emerges as IS in passing from the air through the glass and again into the air, and is called single refraction. Some substances, like Iceland spar, split the ray and cause the two parts to take different directions. Such a change is called double refraction.

FIG. 16.



Refraction through parallel plate.

FIG. 17.



Law of refraction.

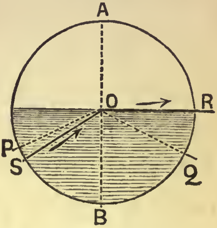
What are the laws of refraction?

(1) For the same media, the ratio of sine of the incident angle and the sine of the reflected angle is constant. In Fig. 17 the media are air and water. The incident ray *RI* of the air becomes the reflected ray *IS* of the water; therefore the ratio of *R′P′* and *SP* is constant.

(2) Light is generally reflected toward the perpendicular when it passes from a rarer to a denser medium, and away from the perpendicular when it passes from a dense to a rarer medium.

(3) A ray emerges from parallel faces at the same angle it entered.

FIG. 18.



Critical angle.

Give examples of the index of refraction.

From air to water it is $\frac{4}{3}$; from air to glass it is $\frac{3}{2}$. Conversely, from water to air it is $\frac{3}{4}$.

What is total refraction, or the critical angle?

It is the limit at which a refracted ray can emerge from a medium. The angle *SOB* (Fig. 18) is the largest that can exist and allow the ray *SO* to emerge into the air, and is therefore the critical angle.

What application has the index of refraction?

(1) It explains some of the illusions of the eye and of optical instruments.

(2) By it the purity of transparent bodies may be determined.

Define an optical prism.

It is a refracting mass bounded by planes inclined at any angle. It may be solid glass or a triangular bottle filled with gas, water, or any other transparent substance.

How does a prism affect light?

(1) The light is refracted.

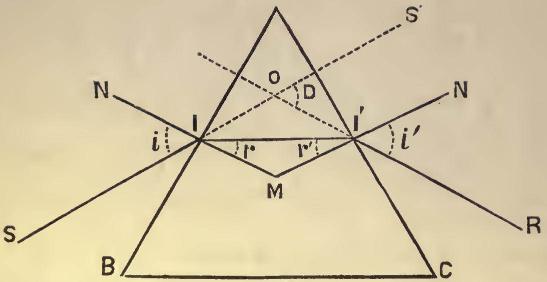
(2) Each ray is separated into constituent rays which are colored. These colors, collectively, are called the prismatic spectrum.

(3) It partly separates the rays of heat from those of light.

Explain the cause of refraction in a prism.

The velocity of light is greater in air than in glass. Retardation of a wave of ether striking *S I* (Fig. 19) at *I* begins at the lower side and progresses until the whole wave front enters the glass. This causes a change of direction maintained by the ray until it reaches the next face, *I′*, at which place it is for similar reasons again refracted.

FIG. 19.



Prism.

Explain the decomposition of light.

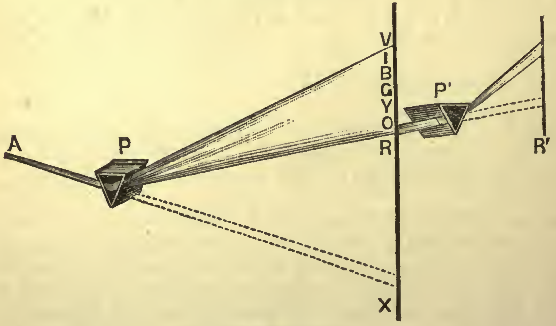
Through a very small opening in the shutter of a dark room admit a beam of sunlight and allow it to pass through a prism and fall upon a screen (Fig. 20). It presents an infinite number of tints which gradually merge into each other. For convenience, seven of these were selected by Newton and spoken of as the *seven primitive colors*, viz., *violet*, *indigo*, *blue*, *green*, *yellow*, *orange*, *red*.

These are the components of white light.

In what order are the colors generally deviated?

The order is that arrangement just mentioned; the violet being deviated the most from the original ray, and the red last. The deviation of the others is intermediate between these.

FIG. 20.



The spectrum.

Can the colors be further separated?

Yes; if the colored rays fall upon a second prism, *A P′* (Fig. 20), their dispersion is further augmented. With other prisms the dispersion may be indefinitely increased.

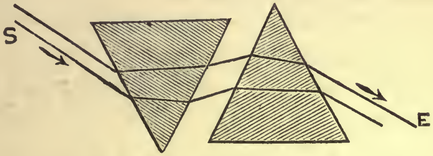
Do all spectra present the same order of color?

The order given is called the normal order, but prisms of different materials disconcert this arrangement. Solutions of indigo and permanganate of potash each give abnormal spectra. A prism filled with fuchsine deviates the red most and the violet least.

Can the colors be reunited to form the original ray?

Yes; if a spectrum produced by passing a ray of white light, *S* (Fig. 21), through one prism be immediately passed through a second prism in every way the same as the first, but inverted, the refraction of the two prisms is opposite in direction, the colored rays are reunited, and a white ray *E* emerges from the second prism.

FIG. 21.



Recomposition of light.

What is Newton's disk?

It is a circular piece of card-board, the seven sectors of which are colored according to the normal spectrum. When revolved rapidly these colors blend as one which is nearly white. Were it possible to give each sector its proper intensity of color, the resultant would be white.

What are complementary colors?

Any two colors or tints which when mixed produce white light are called complementary colors. One of these tints has a part of the seven primary colors for constituents and the other tint contains the remaining ones.

What theory accounts for accidental color images?

After looking steadily for some time at a bright color, if we turn the line of vision to a white wall, an image of the colored object appears in its complementary color. This is explained upon the hypothesis that the nerves which have been strongly impressed by the bright color have so lost their sensibility that the balance of action required to cause the sensation of white is lost, and those factors which have not been exhausted are more strongly impressed. Such subjective results are known as *negative accidental images.*

What is color-blindness?

It is the inability to recognize red. The eye is abnormal and lacks those sensations which represent this color or the product of slow vibrations.

What constitutes color in a body?

It is the nature of all bodies to absorb or to reflect the light which falls upon them. Those bodies whose surfaces are so constituted that they practically absorb all light, reflecting none, are termed *black*, while those which absorb none but reflect all are termed white bodies. Most bodies absorb some light rays and reflect others. They absorb some fraction of primary colors and reflect the remaining portion or complementary color. It is this reflected portion which gives the color.

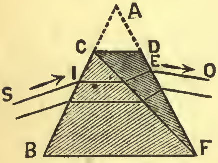
Compare different materials for prisms.

Prisms of the same angle, made of crown glass, flint glass, water, quartz, etc., refract unequally, and when adjusted to refract the red ray through equal angles the violet will be differently deviated. The spectra will have varying lengths. Flint glass gives about twice as long a spectrum as crown glass.

Describe an achromatic prism.

It is a prism so constructed that a ray of light passing through it is refracted, but is not decomposed. Different materials having unlike indices of refraction and dispersion are combined as in Fig. 22. *BCF*, a crown glass section, has its dispersion neutralized by the flint glass section *CDF.*

FIG. 22.



Achromatic prism.

What three important properties belong to the spectrum?

Its heating, illuminating, and chemical properties, each of which has a maximum and minimum point of intensity.

Where are the heat rays located?

Herschell showed that blackened paper moistened with water dried most rapidly in the red rays and less quickly in succession to the violet. Heat was also found in the dark space beyond the red ray. A galvanometer attached to a thermopile is deflected least in the violet and more toward the red, reaching its maximum just beyond at the point called ultra-red.

Compare the illuminating effects of the primary rays.

The eye recognizes the greatest intensity in the yellow. Fine print illegible in the violet becomes more distinct in the red rays and visible in the yellow, at which point the intensity is maximum and decreases toward either edge of the spectrum.

Locate the chemical or actinic intensity.

It is greatest in the violet and decreases abruptly toward the red, but more gradually in the ultra-violet. Organic matter moistened with a solution of silver salts and exposed to light darkens according to the chemical effects of the rays. Experiments based on this fact confirm the statement.

It is evident that if light is the result of vibrations of ether, these vibrations are too slow in the ultra-red and too rapid in the ultra-violet to excite vision.

What are lenses?

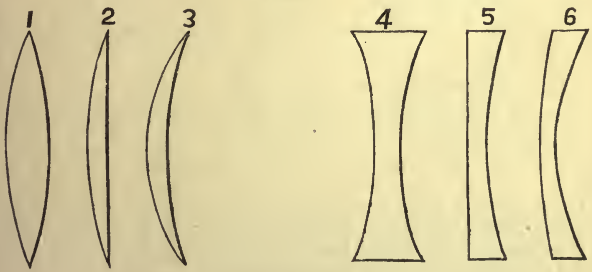
Any transparent medium adapted to transmit rays of light and converge or diverge them constitutes a lens. The main faces are either both spherical surfaces, or one is a plane and the other a spherical face. The curved surfaces may have any radii, either equal or unequal. In practice glass is the generally adopted medium.

How are lenses named?

Lenses whose edges are thicker than their middle are called *concave*, and those whose middle is thicker are called *convex*. See Fig. 23.

(1) Double convex lens: bounded by two faces whose radii are in opposite directions and overlapping;

FIG. 23.



Forms of convex and concave lenses.

(2) Plano-convex lens: bounded by a plane and a spherical surface;
(3) Meniscus: having the radii of its surfaces in the same direction;

(4) Double concave lens: both faces concave;
(5) Plano-concave lens: one face plane, the other concave;
(6) Concavo-convex: one face concave, the other convex.

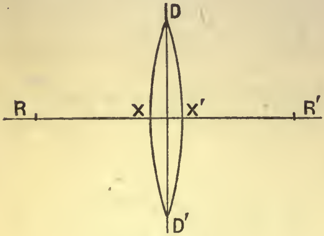
Define the principal parts of a lens.

In Fig. 24 the line RX', by which the curve $DX'D'$ is described, is its *radius of curvature*, and the point on which the radius revolves is the *centre of curvature;* on the opposite side the centre of curvature for DXD' is found.

A line connecting the two centres, and piercing the lens at XX', is the *principal axis* of the lens. Where one surface is plane, the principal axis is the line let fall from the centre of curvature of the spherical face perpendicularly upon the plane face.

The line DD', drawn from one point of the circumference to that exactly opposite, is called the *diameter*. The axis and diameter are perpendicular to each other.

FIG. 24.



Convex lens.

The *aperture* of a lens is the angle between lines connecting the extremities of a diameter with the principal focus.

What is the principal focus of a lens?

It is that point at which parallel rays are brought together after passing through a lens whose arc is less than ten degrees.

What is the focal length?

That distance from the principal focus to the lens is called the focal length.

What cases do convex lenses present?

(1) Parallel rays meeting a convex lens are transmitted and refracted to the principal focus.

(2) Emergent rays from a luminous point at the principal focus are parallel.

(3) Rays from a luminous point on the principal axis at a distance greater than the focus are converged to a secondary focus. The principal and secondary are termed *conjugate* foci.

(4) As the luminous point moves towards the principal focus its conjugate retreats until it becomes case (2).

(5) When the luminous point is less remote from the lens than the principal focus, the emergent rays are somewhat converged, but not sufficiently to produce a focus.

Explain the action of concave lenses.

Concave lenses increase the divergence of light rays; therefore, like concave mirrors, they can have no *real* focus, but a *virtual* one may be found by prolonging the course of the emergent rays backwards through the lens. Their images are virtual, erect, and smaller than the object.

What are the images of convex lenses?

1st. *A large object at a great distance from a convex lens produces a small real inverted image a little beyond the principal focus of the lens, as in an ordinary photographic camera.*

2d. *A small object a very little beyond the principal focus of a convex lens forms a large real inverted image at a considerable distance beyond the principal focus. Illustrated in the case of the projection lantern.*

3d. *In the first case, the greater the distance the smaller the image. In the second, the nearer the object to the focus the larger the image.*

How is spherical aberration of lenses overcome?

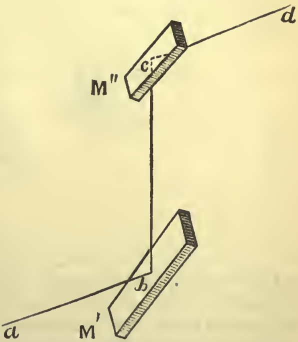
To overcome spherical aberration several methods are employed, the best two of which are (1) to make the boundary surfaces parts of unequal spheres; (2) to combine a concave and a convex lens.

If the radiating point is infinitely distant, the convex surface should be toward it. The radii of curvature for crown glass should be as 1 to 6. As the luminous part approaches the lens the nearer surface decreases its convexity until the principal focus is reached, when the ratio should be reversed, 6 : 1.

What is polarized light?

Light may undergo plane, circular, elliptical, and rotatory polarization. If a ray of light falls on a polished unsilvered glass surface at an angle of 35° 25′, it is not only reflected, but undergoes another extraordinary change; for if the reflected ray is received at the same angle upon another sheet of similar glass, it is most completely reflected when the face of the second mirror is parallel to that of the first, as in Fig. 25, in which *a* is an incident ray of ordinary light reflected from the mirror *M′*, in the direction *bc;* on meeting the second mirror *M″* at *c* it undergoes reflection, following the line *cd;* on rotating the mirror *M″* on its vertical axis, the reflected ray loses its intensity, and when *M″* has moved through 90° the light falling on its surface from *M′* is no longer reflected.

FIG. 25.



Polarization.

To this change in the ray *bc*, in consequence of which it can only be reflected under certain conditions, and fails entirely in others, the term *polarization* is applied. The first mirror is called the *polarizer*, and the second, on account of its action, the *analyzer*.

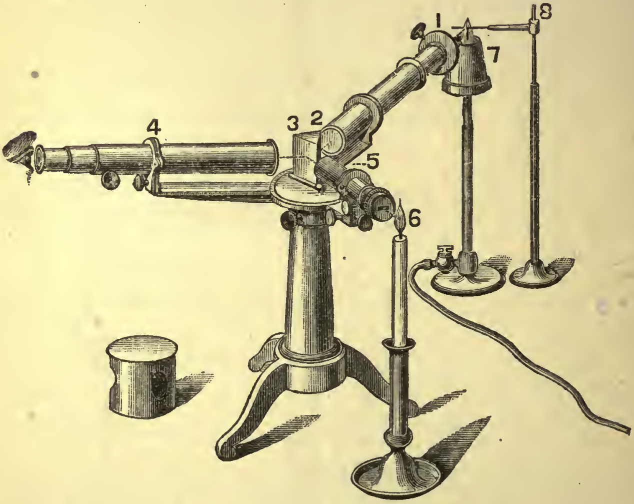
What is the angle of polarization?

It is that angle which the incident ray must make with the perpendicular to the polished surface of any given substance in order to produce complete polarization in the ray reflected from it. This angle varies for different substances, being 54° 35′ for glass, 52° 45′ for water, and 68° for the diamond.

What is the spectroscope?

It is an instrument designed to study light by the formation of a spectrum. The action of the spectroscope being to disperse a mixture of colors into its components, it sometimes may be necessary to use more than one prism for this decomposition. The essentials of the spectroscope are its prisms, a telescope for examining the spectrum, and in some instruments an appliance containing a scale for measuring the bands.

FIG. 26.



The spectroscope.

The substance giving the light to be examined is placed upon the platinum wire *8* (Fig. 26), which is burned in the flame 7, shedding its light through *1* to *2*, where it falls upon the prism *3*, to be examined through the telescope *4*, and measured at *5* by a scale which is illuminated by *6*.

What are the spectra of solids, liquids, and gases?

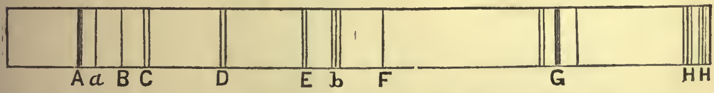
Solids and *liquids* heated to a luminous point give *continuous* spectra, that is, a spectrum of unbroken light; gases or vapors give non-continuous spectra, or only *bands* of light called *banded spectra.*

Every gaseous substance gives its particular lines or bands relative to number, position, and color. These are constant, and when seen in the spectrum always determine the material from which illumination proceeds. The constituents of any gaseous compound give their respective bands of color. Solar light gives bands which correspond in size, number, and position with bands of some of the terrestrial elements. The sun is, therefore, said to contain these terrestrial substances.

Describe the solar spectrum.

Sunlight examined through the spectroscope shows a non-continuous spectrum crossed by numerous dark lines. Each of these dark lines, so far as studied, occupies the position of the colored bands of various substances. A sodium flame produces a spectrum consisting of a bright yellow line. It might be expected that if this was interposed between an oxyhydrogen lime-light and the spectroscope through which it is viewed, the yellow of the former would intensify that of the continuous spectrum of the latter. Such, however, is not the case; on the contrary, the sodium flame absorbs the yellow of the calcium light, and a dark or black line appears in its place. In the same manner potassium, strontium, and other vapors were found to produce dark lines in a continuous spectrum when intervened between the spectroscope and a calcium light. To this class of phenomena the term *absorbent spectra* is applied, and whenever an incandescent vapor forms a spectrum of dark lines it will produce a reverse spectrum of dark lines when intervened between the spectroscope and an incandescent solid or liquid.

FIG. 27.



From these facts it is argued that sodium exists in the outer envelope of the sun, and therefore absorbs the yellow ray of light coming from the luminous interior, thus producing a black line. In a similar way is established the existence or non-existence of other elements in the sun.

These lines of black are known as Frauenhoffer lines, and were named *A*, *B*, *C*, etc., by their discoverer. (Fig. 27.)

Is solar light essential to vegetable life?

Plants deprived of light soon die; those kept for a time in darkened rooms fade or lose their color. Sunlight is absolutely essential to the production of chlorophyll, or the green coloring-matter of the leaves.

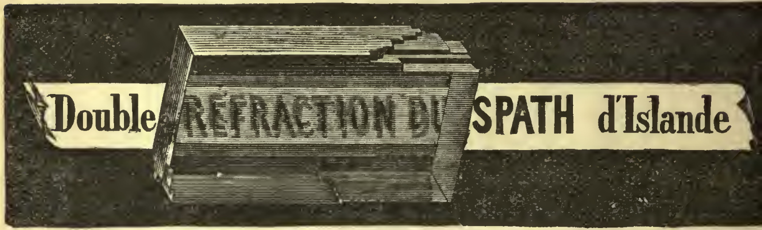
Mention some chemical effects of sunlight.

By direct solar light many chemical substances are made to assume different properties. The salts of silver in conjunction with organic matter blacken, and are thus adapted to photography, which depends on this principle of change of color. Chlorine gas is made active by solar effects.

Explain double refraction.

If a crystal of Iceland spar (Fig. 28) be placed upon a sheet of paper which bears a dark spot or dot, the latter appears double when viewed through the crystal. To this phenomenon of splitting or bifurcation of the pencil of light in its passage the name of double refraction has been given. All crystals not belonging to the cubic system exhibit this property to a greater or less extent. Any double refracting crystal has one axis in which the spot is not doubled. In some crystals no such axes are found.

FIG. 28.



Double refraction.

What is interference of light?

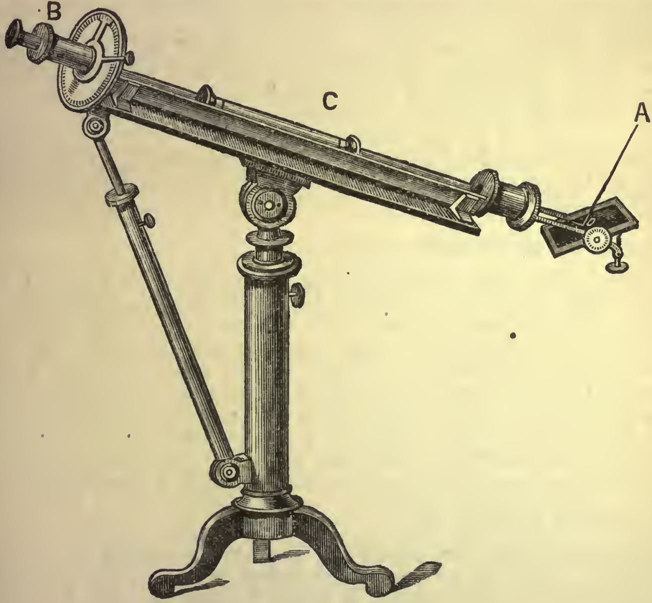
Make two small apertures of the same diameter, and close to each other, in the shutter of a dark room; cover them with a sheet of red glass: two conical pencils of red light will be formed, which meet and overlap each other at a certain distance from the shutter. If a screen is introduced into their path beyond this position, it will be seen that the overlapping segment produces an image composed of alternate red and black bands. On shutting out the light from either aperture the dark bands at once disappear. It is therefore evident that the dark fringes have been caused by the interference of the two pencils when they have crossed, and that, as with sound, two systems of waves may interfere and destroy each other, producing silence, so with light, two systems interfere and produce darkness.

The same results are obtained with any other homogeneous light, the only difference being in the distances of the bands from each other. This experiment is regarded as giving the most satisfactory evidence of the correctness of the undulatory or wave hypothesis of light. In white light the component colors produce dark bands at different intervals, these being superimposed but not coincident; the dark lines of one color are illuminated by the others, and a series of colored bands arise.

Explain the saccharimeter and its use.

Saccharimeters are instruments depending upon polarized light for their action. That of Biot (Fig. 29) determines the amplitude of rota-

FIG. 29.



The polariscope.

tion produced by sugar or other solutions possessing this power. The polarizer in the original form is a mirror of black glass, and the analyzer a double refracting achromatic prism mounted in the interior of a graduated circle, so that changes in position of the prism are read by means of an index traversing the scale. Between these the tube containing the solution is placed, with its axis coincident with the conjoined axes of the analyzer and polarizer. The tube is about 20 centimetres in length. The apparatus is adjusted to have the extraordinary ray disappear when the index is at zero. The introduction of water, alcohol, or ether causes no change in the phenomena observed.

If it is then filled with a solution of cane-sugar, the extraordinary ray reappears, and to cause it to fade the analyzer must be turned to the right of zero through a certain number of degrees, which measures the amount that the sugar has *turned* the plane of polarization to the left. If a longer tube be used with a solution of the same strength, the analyzer must be turned through a greater number of degrees. According as the strength of the solution differs, so does the angle at which the analyzer must be set vary. It is therefore a simple matter to estimate the amount of sugar in any given solution by determining its power to rotate a beam of polarized light.

In the manufacture and refining of sugar the saccharimeter is important, as the sales of this commodity are based upon its indications. In the practice of medicine it is used for determining the percentage of sugar in diabetic urine and in other fluids.

The principle of polarization is further applied to examine the nature and purity of crystals, for the detection of false gems, and to determine whether the light from heavenly bodies is reflected or is light direct from self-luminous bodies.

What is the photographic camera?

The camera consists of an achromatic lens mounted in a wooden box, at the back of which is a ground-glass plate for the reception of the image projected by the object before the lens. The image is focussed on the ground-glass, which is then removed and replaced by a "holder" containing a sensitized plate. Light is then admitted for an instant through the lens, and the background of the image is darkened, while the image itself remains light. This plate is called the negative, because when placed over sensitized paper and exposed to the sun it admits light through the image and excludes it from the background, thus making the colors on the paper the reverse of those on the glass.

Explain the stereopticon.

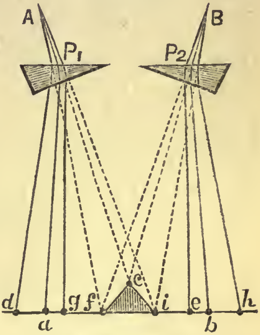
The stereopticon is the converse of the camera. It is used to project magnified images on a screen in a darkened room. A transparency or slide, produced by the camera, is placed between the two lenses of a stereopticon and its image, inverted and enlarged, is produced on the screen. This is accomplished by confining a light within the stereopticon and causing its emitted rays to pass through a convex or condensing lens, thence through the transparency, and lastly through a movable focussing lens which inverts and magnifies the shadow or image.

Describe the stereoscope.

The stereoscope is an instrument by which two pictures of the same object taken at a proper angle may appear as one. Each eye sees only the picture opposite it, but by suitable contrivances the two images are made to coincide and appear in the same place.

"Let the left eye be at B (Fig. 30), and the right at A; let a and b be the corresponding pictures for each eye, and P_1 and P_2 two prisms of glass through which they are seen. A prism refracts rays of light so that objects viewed through it appear to be nearer to the refracting edge; the prism P_1, therefore, refracts the ray aP_1 in the direction P_1A, as if it proceeded from c. The prism P_2 refracts the ray bP_2, so that to the eye at B it also appears to proceed from c. The effect of this is—provided that the two pictures a and b are drawn just as a body at c would appear to the eyes at A and B if the prisms were not there—that the object really appears to be at c. And as the points a and b combine to form the point c, so d and e unite to form the point f, g and h to form the point i."

Fig. 30.



The stereoscope.

Similar effects of relief may be produced by the projection on the same spot of two photographic images of any object taken at a suitable angle to each other.

How do we estimate the size and distance of objects?

Our estimation of these depends: 1st, upon comparison with those of known size in the same locality; 2d, upon the visual angle; 3d, upon the optic angle. Regarding the latter, Ganot says: "This angle increasing or diminishing according as objects approach or recede, we move our eyes so as to make their optic axes converge towards the object which we are looking at, and thus obtain an idea of its distance. Nevertheless, it is only by long custom that we can establish a relation between our distance from the objects and the corresponding motion of the eyes. It is a curious fact that persons born blind, but whose sight has been restored by an operation for cataract, imagine at first that all objects are at the same distance."

What is the principle of the compound microscope?

The principle of the compound microscope is to produce an image by the aid of a lens and to magnify this image by one or more lenses before it reaches the eye. Suitable adjustments for focussing and illuminating the object are a part of the instrument. The microscope is used to examine near objects too small to be seen distinctly by the unaided eye.

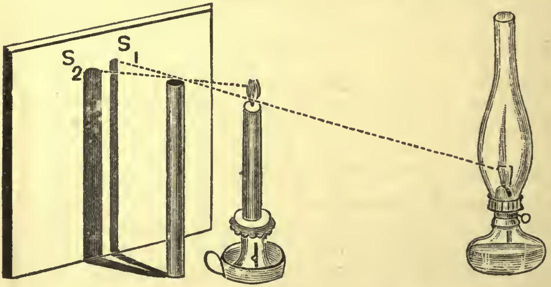
What is the use of the telescope?

The telescope is used to view objects which appear small on account of their distance. It consists of an object glass which forms a real image, inverted but small. This image is viewed through a microscope and seen in an inverted position. If the telescope be used for terrestrial purposes, two additional lenses must be inserted between the eye piece and the object lens in order to bring the image to an upright position.

How is the intensity of light measured?

The intensity of light is measured by comparison. The standard is called candle-power. It is the light given by an English sperm-candle burning at the rate of 120 grains per hour. A transparent disc is illumined on one side by the standard candle and on the opposite side by the light to be tested. The disc is then slowly moved along a graduated scale which joins the two lights until both sides are equally illuminated. The distance to each light is then observed, and the intensity computed on the principle that the intensity of light is inversely as the square of the distance. Rumford's photometer is an opaque rod placed at a short distance from a screen; the two sources of light are then arranged, as in Fig. 31, so that each forms a shadow of the rod

FIG. 31.



Illumination photometer.

upon it. The lights are then moved until the shadows are of equal intensity. Since that from the lamp is illuminated by the candle, and that from the candle by the lamp, the illumination of the screen by the sources of light is equal. The intensities of the lights are, therefore, as the squares of their distances from the screen.

MAGNETISM.

What is a natural magnet?

Lodestone is the only natural magnet known. It is an oxide of iron (Fe_3O_4), or often a compound of two oxides, and it occurs as an ore, fragments of which, when suspended, tend to point north and south. They were therefore called leading stones or lodestone. The Greeks applied to the ore the name *magnus*, from Magnesia, the city near which it was found. Its property, termed magnetism, is to attract iron.

What are artificial magnets?

They are made from a few substances which are capable of receiving magnetism. Of the eligible substances, such as cobalt, nickel, and steel, the latter is almost invariably used.

What are the varieties of artificial magnets?

Bar magnets, horseshoe magnets (Fig. 32), and magnetic needles. Other shapes may be made, but these are the most convenient forms.

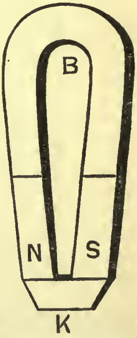
Is the magnetism of a magnet permanent?

Much depends on the material and the shape of the magnet. Those called permanent are made, but in time their power is enfeebled or totally lost. A piece of soft iron, an armature, joining the ends of the horseshoe, guards against the decrease of force.

What is a compound magnet?

Several bars or horseshoes, separately magnetized and riveted together, give better effects than the same amount of iron in one magnet. When great force is required, this compound form (Fig. 33) is used.

FIG. 32.

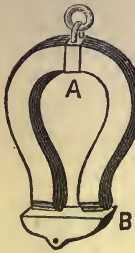


Horseshoe magnet.

What are the properties of magnets?

Attraction and repulsion. Substances of one class, such as iron, steel, cobalt, nickel, and platinum, are more or less easily attracted, and are therefore termed *paramagnetic* bodies; those of another class, such as bismuth, antimony, zinc, tin, mercury, lead, silver, copper, gold, and arsenic, are

FIG. 33.



Compound magnet.

repelled by a magnet, and hence receive the name *diamagnetic.* Successful experiments with the latter class require a strong magnet.

Do magnets attract through other bodies?

Not through all others. Paper, slate, glass, etc., placed between a magnet and a bit of iron, do not intercept the attraction; but a partition of iron does impede the magnetic influence. Magnets attract in vacuo as well as in air.

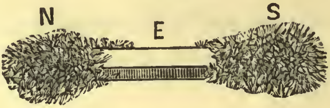
What is polarity?

A bar magnet poised horizontally and attaining a state of rest assumes, within certain limits, the direction of the earth's poles. The end pointing north is usually marked and called the north pole; the opposite end is the south pole. These names are, however, sometimes interchanged.

Do all parts of the magnet manifest the same power?

No. By placing a magnet in iron filings it may be shown that the ends exhibit the most attraction. The filings cling tenaciously to the termini and are less affected as we approach the middle point, which is neutral (as shown in Fig. 34).

FIG. 34.



What are the laws of attraction and repulsion?

(1) Like poles repel and unlike poles attract.

Two magnets placed with the north or the south poles contiguous will repel each other, but a north and a south pole mutually attract.

(2) The force exerted between two magnetic poles, attracting or repelling, is directly proportional to the product of their magnetic strengths and inversely proportional to the square of the distance between the poles.

Are the two poles inseparable?

They are. If by any means a piece of iron becomes a magnet, one end is always a north and the other a south pole. Broken in pieces, each part becomes a magnet, with its opposite poles; but the reunited fragments retain only their original poles.

How is this fact explained?

It is understood by saying that each molecule is a magnet in miniature and that each north pole indicates the same direction. Two molecules adjacent present unlike poles to each other and neutralize that point.

What is magnetic induction?

A piece of soft iron brought near a magnet or in contact with it attains magnetic properties. It will attract as if it were a part of the magnet. Separate it widely from the influence of the magnet, and its polarity no longer exists; the magnetism was temporary or induced while the iron was in contact with the magnet or near it. This fact of magnetism is termed induction.

How are artificial magnets made?

Several methods are employed :—

(1) *The simple touch:* The bar to be magnetized is laid upon a table and several times stroked in one direction with a piece of lodestone or an artificial magnet.

(2) *The double touch:* This implies stroking the bar from the middle to one end and back to the middle with the opposite poles of two other magnets separated by a bit of wood.

(3) *The separate touch:* This methoa uses two magnets, the opposite poles of which are placed on the middle of the bar and simultaneously moved away from each other toward the ends.

(4) A bar of iron placed in the earth at or near a magnetic centre becomes a magnet.

(5) When a bar of soft or wrought-iron is held in the magnetic meridian parallel to the inclination, it becomes immediately a temporary magnet. If, while held in the proper position, a few blows are struck with a hammer, it retains its magnetism for a short time. If it is twisted, only a feeble charge is developed.

Discuss the power of magnets.

A magnet which has received its full development of force is said to be saturated. Among the causes which produce variation in strength is tempering of the steel employed.

The harder the steel, the greater its coercive force. It is more difficult to magnetize, but it retains the charge better. The property of a magnet is also dependent upon the percentage of carbon contained in the steel. This also causes a variation in the degree of heat at which it should be tempered. Compass needles are generally tempered at a blue, which is about 300° C.

Increase of heat diminishes intensity of magnetism in a bar; heated to a bright red it completely loses it, and it is not regained with return to its original temperature.

Hammering a steel bar while being magnetized increases its power. If, on the contrary, a magnet is allowed to fall, or struck a strong blow, it is in part demagnetized.

What is an astatic needle?

A combination of two magnets or magnetic needles placed parallel on a common axis and adjusted with their unlike poles adjacent assume no particular direction relative to the earth's magnetism, but remain in whatever direction they are placed. Remove one of the needles, and the other immediately points toward the magnetic centres. Such a combination of needles neutralizing each other is termed astatic.

Describe the earth's magnetism.

As the earth affects a poised magnet precisely as another magnet would do, attracting and repelling, we may assume it to be a globular magnet of immense size and great strength. Just how its magnetism is engendered is unknown, but experiments prove its existence and show that the earth has magnetic centres and is affected by magnetic currents.

What are the magnetic poles of the earth?

Regarding the earth as a magnet, it must have two points corresponding to the north and south poles of any other magnet. These two centres of magnetic force are the magnetic poles of the earth. *They do not coincide with the poles of the earth's axis.*

Where are the magnetic poles located?

One is in latitude 70° 5′ north and longitude 96° 45′ west, a place north and west of Hudson Bay. The other was located in Victoria Land in 1831 by Sir John Ross. These centres are not constant, and therefore cannot be located like a town. They move westward and back eastward within certain limits, requiring a long period of years to complete a single journey. They require about twelve years to move a single degree.

Does the magnetic needle always point directly north and south?

It does not. It is governed by the magnetic poles, and therefore varies when placed either east or west of the magnetic meridian or line joining the two magnetic centres, termed the *line of no variation.*

Is this line of no variation constant?

It is very inconstant, but moves eastward and westward within known limits and periodically makes its journey from west to east. The compass needle therefore points to the north and south only when the magnetic meridian happens to coincide with the terrestrial.

What is declination or variation?

It is the angle which the axis of a magnetic needle makes with the geographical meridian of a place. It is said to be east or west according as its north pole is east or west of this meridian.

At present the declination is to the west in Europe and Africa, but to the east in Asia and North and South America. It shows variations either annual or diurnal, regular or irregular. The latter are called magnetic storms.

At London, in 1580, the declination was to the east 11° 36′; in 1663 it was at zero. Since then it has gradually moved to the west, reaching the maximum of 24° 41′ in 1818; thence slowly working its way eastward, and in 1879 was at 18° 10′ west.

What is the dip of a magnetic needle?

A compass needle always inclines toward the perpendicular as it approaches a magnetic pole, and the angle which it makes with the apparent level is its *dip*. This angle is 90° at the poles and 0° at the magnetic equator. To overcome the inconvenience which the dip might impose upon observations, the needle is usually kept in equilibrium by a movable wire or weight placed near one end.

Where is the magnetic meridian located?

The magnetic meridian is a zigzag line making a meridian approximating a great circle passing through the magnetic centres. As the centres are constantly changing, moving eastward, then westward, within certain limits, the complete route occupying centuries, the meridian itself is also more or less inconstant.

How does heat affect a magnet?

A magnet heated to a white heat loses its magnetism, and similarly a piece of soft iron heated to redness is unattracted by a magnet.

ELECTRICITY.

STATIC ELECTRICITY.

What is the nature of electricity?

It is a powerful physical agent or force, manifesting itself mainly by its attraction and repulsion, by heating and luminous effects, by chemical decompositions, and by its importance to life. For convenience it is designated a fluid.

Do all bodies possess this electric force?

All bodies in a state of rest possess it to a greater or less degree, in an inert condition called *static*. It is, however, not evoked with equal readiness and intensity from all bodies. Amber, sulphur, glass, sealing-wax, caoutchouc, and many other substances, when excited by friction, develop an attraction for minute objects, such as cotton and silk fibre, paper and cork, etc. This attraction soon ceases and the electric force soon reverts to an inert state.

What experiment suggests two kinds of electricity?

Suspend near together, but not in contact, by silk thread, two tufts of cotton, then touch them both with a glass rod which has just been rubbed with silk. The cotton balls will repulse each other for a short time, then regain their original position. Repeat the process with a piece of sealing-wax which has been rubbed with flannel; repulsion again occurs. Lastly, after exciting the rods by friction, touch one of them to one of the balls and the other to the second ball. Attraction instead of repulsion ensues between the cotton tufts, and suggests that the influence stored in the glass differs from that of the sealing-wax. Or on a convenient support balance an excited glass rod and bring near it another excited glass rod. The former will be repelled. It will, however, be attracted by excited ebonite or sealing-wax.

What names have been given to the opposite natures?

That force exhibited by the glass has been denominated vitreous or positive electricity, indicated by the sign +, plus; that of the sealing-wax is termed resinous or negative electricity, and bears the sign —, minus.

What are the two theories regarding electricity?

(1) *The one fluid theory*, which supposes that every body has its normal or natural charge in a state of equilibrium, and that by friction or other disturbance the fluid, whether positive or negative, residing in the body is determined. Franklin said that we have but one kind of heat. Cold is a deficiency of heat, therefore it is analogous to say there is but one kind of electricity, and this becomes "positive" when increased or "negative" when diminished. The terms positive and negative, like heat and cold, are relative terms.

(2) *The two fluid theory:* This contends that every body contains the positive and the negative electricities as distinct fluids in neutralizing proportions until disturbed, at which time one of the fluids manifests its character and thus classifies the body. Whenever any two different substances are rubbed together one manifests positive, the other negative electricity.

What are the laws of attraction and repulsion?

(1) The electric force decreases as the square of the distance increases.

(2) Like electricities repeal; unlike attract.

(3) At a given distance the attractive and repulsive forces of electrified bodies are as the product of the quantities of free electricity they contain.

Exclusive of friction, how may electricity be excited?

If a disk of wood covered with oiled silk, and a metal disk, each provided with insulated handles, are pressed firmly together and then separated suddenly, the latter is found to be electrified. A crystal of Iceland spar pressed between the fingers becomes positively electrified; cork, rubber, and a number of substances exhibit the same property if insulated. Sudden separation of bodies develops the best effects.

Cleavage also produces electric disturbance; mica, paper, and all poor conductors, if suddenly separated in the dark, give a flash of phosphorescent electric light. If glass handles are fitted on each side of a piece of mica, and it is suddenly torn asunder, one piece shows positive and the other negative disturbance. A stick of sealing-wax, if broken, shows different electric conditions in its two ends.

Other sources of electricity, such as chemical action and magnetism, exist. Heat also develops electricity in many substances, tourmaline and cane-sugar being examples.

How is the kind of electricity in a body determined?

By exciting the body and presenting it to another having a known electrification, and observing the law that like electricities repel and unlike attack. Glass rubbed with silk becomes positive, with flannel negative.

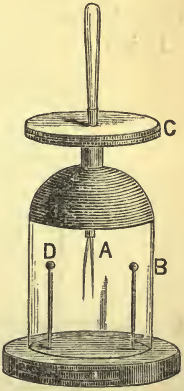
What are insulators?

Substances are good or bad conductors according to the facility or reluctance with which they receive and convey electricity. An electrified body placed on a metal support would quickly lose its charge through the ability of the metal to convey away the electricity. The charge can, therefore, be much longer retained by using for a support some non-conductor, like glass, ebonite, silk, or resin. Insulators are supports or coverings of some non-conducting material which guards electricity and prevents its escape.

How is the presence of electricity detected?

By an instrument termed the electroscope, the simplest form of which is two bits of cork or cotton suspended by silk. These diverge in the presence of electricity. Gold-leaf is very sensitive and makes a very delicate electroscope. Through the stopper of a glass jar (Fig. 35) passes a metal rod terminating with a knob or disc, *C*. To the lower end are attached two strips of gold-leaf, *A*, face to face. These diverge whenever an electrified body is presented to *C*, but discharge themselves if the divergence is sufficient to produce contact with the two metal rods *D* and *B*. The electricity passes through the rod *C* to *A* and electrifies the gold-leaf with the same kind of electricity, therefore they repel each other.

FIG. 35.



Gold-leaf electroscope.

To what part of a body is the electricity confined?

Electricity always resides on the surface. If a hollow sphere having an opening on one side be insulated by mounting it on a pedestal of ebonite or glass, and then charged and tested in various parts by the electroscope, the exterior will show the presence of electricity, while the interior is neutral.

The same evidence is shown by substituting for the sphere a conical bag of linen held open at the base by a hoop. The charged bag shows no electricity on the inside, even though it be turned inside out by a silk thread attached to its apex. The electricity is exterior on the unturned or turned bag.

Does electricity distribute itself evenly over every surface?

No. It has the greatest tendency to escape at *points;* therefore it has its greatest density at or near points, edges, and corners. It has uniform density on the surface of a sphere. On an ellipsoid it is greatest at the ends, while on a flat disc it is principally at the margin.

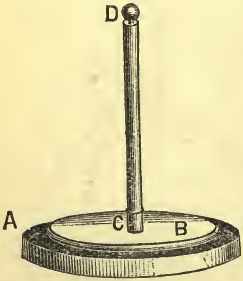
What is induction?

Every electrified body surrounds itself by electric influence, and when thus excited and presented to a conductor, unelectrified and insulated, the neutral fluid of the insulated body is resolved into its positive and negative constituents, the one attracting, the other repelling, the fluid of the first body. An insulated body excited by the presence of an electrified body, although not in contact with it, is said to be electrified by induction. It has its neutral fluid decomposed. The electroscope may be charged by induction if brought into the field of electric influence of some charged body.

What is the electrophorus?

It is an instrument by which electricity is obtained continuously and at a minimum of expense. It consists of a metallic ring (Fig. 36) ten inches in diameter, *A*. It should be about half an inch high. In the circular space thus formed, melted shellac is poured and allowed to rest. A disc of metal, *B*, of less diameter than the shellac is provided; to its centre an insulating handle, *CD*, is attached.

FIG. 36.



Electrophorus.

The shellac is excited by beating it with a catskin or flannel; then lower the plate or cover upon it, touch the margin of the former, and a spark escapes; separate it from the shellac, touch its margin, and another is obtained. So an indefinite number can be drawn from the movable metallic plate by alternately touching it with the finger when laid on the shellac, and separated from it.

What is the meaning of electric potential?

If two bodies are charged oppositely and placed in contact, electricity will flow from the positive to the negative until neutralization takes place. The former is said to have the higher potential or electricity positive to that with which it is compared. Contiguous bodies of the same potential have no exchange of electricity, as it always flows from a higher to a lower potential.

What is the unit quantity of electricity?

It is that quantity which will attract an equal quantity at a distance of one centimetre (0.3937 inch) with the force of one *dyne*. A dyne is that force which produces a velocity of one centimetre when acting for one second upon a mass of one gram.

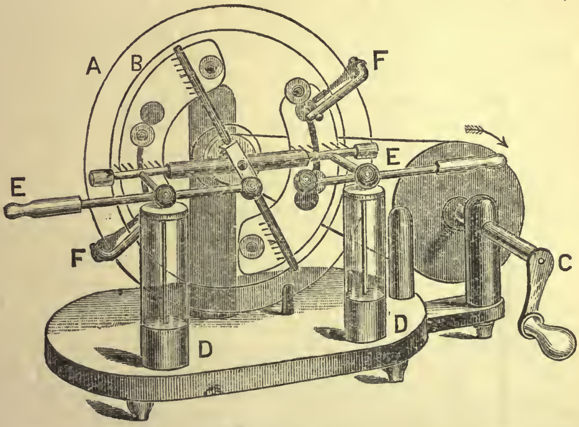
What are electric machines?

They are machines for generating frictional electricity. The earliest and simplest forms were wheels or cylinders of sulphur or glass revolved against a rubber, thus evoking more or less electricity. The machine which has superseded these is more intricate and efficient, and is called the Toepler-Holtz machine.

Describe the Toepler-Holtz machine.

It consists of two glass plates (Fig. 37), one fixed, *A*, and the other, *B*, capable of rapid rotation by a multiplying wheel and band, *C*. Condensers, *DD*, and discharging rods, *EE*, also form parts of the appa-

FIG. 37.



Toepler-Holtz machine.

ratus. The metallic brushes, *FF*, should touch the small brass knobs, but not the plate.

The machine being ready, see that the plate revolves freely without striking anywhere; then place the discharging balls close together and turn the wheel until sparks pass between them; then separate them gradually with a piece of hard rubber. Turning the wheel rapidly, a torrent of sparks passes between the knobs.

The action is this: "The small brass discs on the anterior surface of the plate, when this is revolved, rub against the metallic brushes; a small amount of electricity is thus developed and carried around to the armatures upon the back of the large stationary plate. The initial charge is thus given to this, which in its turn reacts upon the revolving plate. By this novel arrangement the old-style plate with windows is dispensed with and the machine easily charged," the action throughout being by induction.

By means of this machine the application of this form of electricity for medicinal purposes is made a practical success.

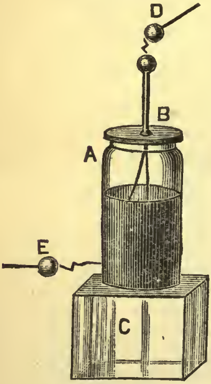
What is an electric condenser?

It is a mechanism for storing electric charges heavier than those contained by the charging body. Many forms have been in use, but the Leyden jar is among the most serviceable and convenient.

Describe the Leyden jar.

It consists of a large-mouthed glass jar, *A* (Fig. 38), coated externally and internally, nearly to the top, with tin-foil and supplied with a wooden stopper, *B*, through which passes a metal rod attached to a chain, also of metal and sufficiently long to coil upon the lining foil. The outer end terminates in a knob.

FIG. 38.



Leyden vial.

How is the jar charged?

If the arrangement be put upon an insulated stand, *C* (Fig. 38), and placed near the prime conductor, *D*, of a machine in action, only three or four sparks pass to it. If a knob, *E*, in electric communication with the ground is then brought near the exterior coating, a spark passes to it. For every one passed from the machine to the inner coating another passes from the outer to the knob. This continues for some time, a perfect torrent pouring from the machine to the vial. At last it ceases and the jar is fully charged. Examination shows that if positive electricity is communicated to the inner coating it is positive electricity which escapes from the outer; but it is not the same as that which the inner coat received, for a time arrives at which the action ceases. That the electricity received by the inner coat is still there may be proved by discharging the vial, when an exceedingly powerful spark is obtained and a profound shock experienced, far exceeding in strength that of the sparks communicated to it. A shock will be experienced if *one* hand be placed upon the knob and the other upon the outer coating. The muscular contraction produced by this means is considerable and often dangerous.

How is the discharge usually effected?

By means of a curved or jointed metal rod terminating with a knob at either end and supplied with a handle of glass or ebonite. Touching one knob to the outer foil and at the same time bringing the other near to the knob of the jar elicits one or more sparks until the jar is discharged.

Describe the jar with movable coats.

Three tumbler-shaped jars are so fitted that a slight difference in size allows them to be placed one within another. The middle jar is of glass, the outer and inner jars of tin. When charged the jars can be separated and the two of tin discharged. They give feeble results. The three are again combined and discharged, with an effect showing that the chief charge resided in the glass.

What is a Leyden battery?

It is several jars so arranged that the outer coatings have communication in one series and the inner in another. Thus constructed they act as a single jar so intensified as to give severe or even fatal shocks.

What are the effects of electric discharges?

Objects receiving the discharge are affected according to their conductivity. Bad conductors are penetrated or shattered, heat is developed, and muscle is contracted. A card placed in the path of a spark from a machine or jar will be perforated. The aperture, however, will not be frayed on one side only as would be the case if a charge had passed from one side to the other. It is frayed on both sides of the card, as if two charges had met within the card and emerged in opposite directions. This fact gives an argument in favor of the two fluid theory.

Among the results of the action of powerful discharges are "burns, superficial and deep, ecchymoses, stripping of the skin off the whole body, deafness, amaurosis, paralysis, lesions of the vascular system, transudations of liquids, and rapid putrefaction. Sometimes the bones are broken, the limbs torn and separated. In one instance the head of a man struck by lightning was crushed as by a powerful blow. On the other hand, strokes of less intensity have cured old diseases.

How is lightning produced?

As heat, friction, evaporation, and condensation develop electricity, it is probable that these agents are responsible for much or all of the electric disturbance of our atmosphere. Wind-driven gases, vapors, and solid particles coming in contact with each other and the earth generate electricity, which accumulates in clouds and is then surrendered to objects having a lower potential, such as other clouds and the earth.

Dry snow driven by the wind creates electric excitement and gives credence to this theory.

State the use of lightning-rods.

They are good electric conductors which tend to guide the course of lightning from the atmosphere to the earth and thus protect objects to which they are attached. Electricity always follows the path of least resistance, and, therefore, will follow a good conductor in preference to a bad one. The rods are usually made of steel or copper held in place by insulated supports. The lower end should penetrate moist earth or some other good conductor, while the upper end should terminate in a point projecting several feet above the adjacent parts of buildings.

What space is protected by a lightning-rod?

The space protected is a field, nearly conical, whose height and basal radius are the height of the rod.

What is the duration of an electric spark?

It is very brief, lasting from 23 to 46 ten-millionths of a second, the time being prolonged by the distance through which the spark travels. This is ascertained by rapidly revolving a card attached to clock-work, each of whose sectors is painted a color in the order and shade or tint of the spectrum. The blending produces a gray color until illuminated by an electric spark. The colors then stand sharply defined as if in a state of rest, showing that the spark has come and gone before the card had time to move.

What is the aurora borealis?

Owing to the fact that the magnetic needle and other electric apparatus are disturbed by its presence the luminous effects seen in the northern region are believed to be of electric origin.

How may a body be protected from electric influence?

It is shown that the electroscope, enclosed by a metal case or a screen of copper gauze, is unaffected by external electricity. Excited bodies presented to the gauze, discharge themselves through the metal without influencing the electroscope. This principle has its application in protecting storages of explosive and inflammable material.

DYNAMIC, VOLTAIC, OR CURRENT ELECTRICITY.

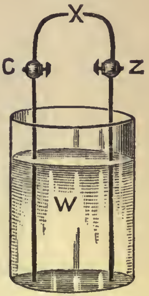
How does static electricity differ from Voltaic?

It differs in its origin and constancy. The former is a condition of tension, and its escape is instantaneous or nearly so. The latter is generated by some action tending to produce a current, which flows without cessation until the generators are withdrawn or enfeebled.

Describe a Voltaic cell.

By placing a strip of copper and one of zinc (Fig. 39) in a vessel containing dilute sulphuric acid, and connecting them above the liquid by a metal conductor, a current or flow of electricity is produced. Volta discovered this action by using an even number of alternating plates of zinc and copper separated by cloth wet with the acid, the first and last plates being connected by wire. The acid acts more vigorously upon the zinc than upon the copper, and creates within the liquid a current of electricity toward the copper and through the wire a current toward the zinc. This action continues while the plates are connected and the material unexhausted. Zinc in a pure state is quickly consumed by the action of the acid; hence to avoid its rapid dissolution it is usually dipped in mercury previous to using. The current engendered is feeble compared with the discharge of a Holtz machine.

FIG. 39.



Simple cell.

Of what metals may a battery be constructed?

In order to establish a current, it is necessary that one of the two metals selected have a greater affinity than the other for the acid. As a matter of economy, preference should be given to the durability of the metals. If chemical action create equal potentiality in the two metals, there will be no current.

Explain the difference between quantity and intensity.

The normal charge which any body possesses at all times and under all circumstances is its quantity of electricity. This charge may be neutral or excited. In the latter case, either the + or — is in excess; and if one species were entirely withdrawn and the other substituted in its place, the *quantity* would remain invariable, but the *kind*, and therefore the *intensity*, *tension*, or *density*, would be increased. Intensity is the available excess of one of the electric fluids.

How are quantity and intensity obtained?

By increasing the *size* of the plates used an increase of *quantity* is obtained. *Tension* or *intensity*, however, depends on the *number* of cells employed, five hundred producing an electric arc several inches in length, while fifty make a very serviceable battery.

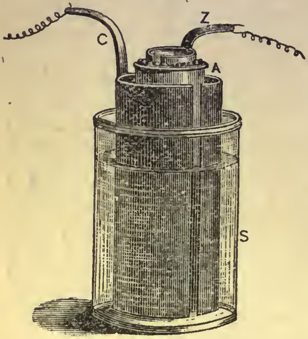
What is polarization of the plates?

The chemism of zinc and sulphuric acid is to produce zinc sulphate and liberate hydrogen gas. The latter collecting in bubbles on the surface of the copper plate, decreases or totally destroys its efficiency by offering resistance or causing a counter-current, a condition termed *polarization of the poles.*

How is the difficulty of polarization obviated?

It is diverted by introducing into the battery a porous cup and some oxidizing substance to unite with the liberated hydrogen, and thus prevent the accumulation. Many kinds of cells have been constructed on this principle. We therefore have "one fluid" and "two fluid" batteries.

Fig. 40.



Daniell's cell.

Describe Daniell's battery.

It is the standard of batteries, and one of great constancy. It consists of amalgamated zinc, *Z*, and copper, *C* (Fig. 40). A glass cell contains saturated cupric sulphate, *S*. Inside of the copper cylinder fits a porous cell containing sulphuric acid, *A*, and into this the zinc *Z* dips. The free hydrogen passes from the zinc to the cupric sulphate, producing sulphuric acid and freeing copper, which immediately collects on the copper plate. Its electro-motive force or difference of potential is 1.00.

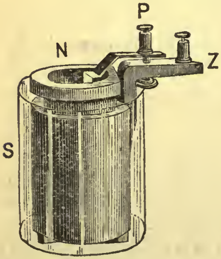
Describe the Leclanche battery.

Liquid, saturated solution of ammonium chloride. Electro-positive metal, amalgamated zinc. Electro-negative element, a porous cell occupied by a carbon plate, the remainder being filled with oxide of manganese, in coarse powder, and small pieces of gas-carbon. Electro-motive force, 1.32.

Describe Grove's battery.

Dilute sulphuric acid is placed in the glass cup *S* (Fig. 41). In this is put the zinc *Z*, also the porous earthenware jar *N*, containing nitric acid and platinum, *P*. Electro-motive force, 1.82.

Fig. 41.



Grove's cell.

What is the Grenet or bichromate battery?

It is a battery much used by physicians, and consists of two plates, one of zinc and one of carbon, contained in a liquid whose proportions are one pound of sulphuric acid, one pound of potassium bichromate, and 20 pounds of water.

Describe the arrangement of cells in a battery.

Cells may be so adjusted as to augment either the intensity or the quantity of electricity. If quantity be desired from any number of cells, say 40, all the zincs would be united for one pole and the carbons for the opposite. The intensity would be that of a single cell, but the quantity equal to 40. Now if required to obtain the greatest intensity, the cells would be coupled alternately. In a Grove battery it would be zinc, sulphuric acid, nitric acid, platinum; zinc, sulphuric acid, nitric acid, platinum, and so on for 40 variations. In this case the theoretical value of the result would be: quantity 1, intensity 40.

Again, a battery might be coupled in two series of 20 each, giving quantity 2, intensity 4; or four, giving quantity 4, intensity 10; or the opposite, viz., quantity 10, intensity 4.

It is understood that full values are never obtained in practice, resistance and other causes reducing them materially.

When the positive plates are connected by one wire and the negative plates by another, they are joined in *multiple arc.*

They are joined *in a series* when the positive plate of one cell is connected to the negative plate of the next.

What is the resistance of a cell?

There are two kinds of resistance, external and internal. The former is that which impedes the current tending to flow outside of the cell or *away* from it; the latter is that resistance encountered *within* the liquid and plates constituting the cell. Their difference is the difference of work done within the cell or battery compared with that done outside. The external resistance compared with a standard of resistance can easily be measured.

What is the unit of resistance or electric measure?

The unit of resistance is called the *ohm.* It is the resistance offered by a column of pure mercury 104.81 centimetres long, 1 square millimetre in section, at a temperature of 0° Centigrade. For practical use, coils of wire having this same resistance are used. The wire is an alloy of two parts of silver to one of platinum. As the resistance differs with the temperature of the wire, each coil is marked with the exact temperature at which the resistance is one ohm.

Boxes containing coils of varying lengths, and therefore of different resistances, are also constructed. They may measure fractions or multiples of an ohm. This unit is called the B. A. or British Association unit. It was established in 1860.

At what rate does resistance increase and decrease?

(1) Calling the electro-motive force that which tends to impel a flow of electricity from point to point, its constancy induces a constant current in a given wire.

(2) Doubling the length of the wire doubles the resistance, while it halves the current.

(3) The electric resistance is increased by diminishing the circumference of the conducting wire, and *vice versa.* The conditions of length,

material, etc., remaining the same, halving the cross-section doubles the resistance and halves the current.

(4) All resistances may be measured by the ohm. They depend upon the material relative to its length, cross-section, and conductivity.

How do we measure electro-motive force?

(1) The standard chosen for the unit of electro-motive force or power to overcome resistance is called the *volt*. It is a little less than the force of a Daniell cell, which is from 0.98–1.08 volts.

(2) The *weber* is the unit of current. It is the electro-motive force of a volt working through the resistance of an ohm.

What is Ohm's law?

It is expressed by the equation :—

$$\text{Current} = \frac{\text{Electromotive force}}{\text{Resistance}} \text{ or } C = \frac{E}{R}.$$

The current is directly proportional to the electro-motive force and inversely proportional to the resistance. Any two of these terms being known determines the third.

What is the formula for resistance and conductivity?

The resistance is the reciprocal of the conductivity; or—

$$\text{Resistance} = \frac{1}{\text{Conductivity}}; \quad \text{Conductivity} = \frac{1}{\text{Resistance}}.$$

How is internal resistance measured?

$$\text{Internal resistance} = \left(\frac{\text{Distance between the plates}}{\text{Area of the plates under the liquid}}\right) \times P.$$

P is a number taken from a table based on the diameter, length, and material of wire according to known laws.

What are divided circuits or currents?

If the electrodes or polar wires be branched or split in several parts, the current will also divide, flowing through each branch in inverse proportion to their resistance. With equal divisions of the wire each section will receive the same fraction of the entire current, and in all cases the currents will be inversely as the cross-section of the branches. This knowledge is often applied to measure currents which are very strong. It is also serviceable to divide a current whose parts are to do work independently.

What is the galvanometer?

It is a mechanism to determine the strength and direction of a current (Figs. 42 and 43). A wire placed above or below a magnetic needle and parallel to it will, when receiving a current of electricity, deflect the needle to right angles with itself. Suppose a person placed parallel to the wire and *facing* it, but on the side away from the needle, and the current be directed as if from his feet to his head the north pole will

FIG. 42.

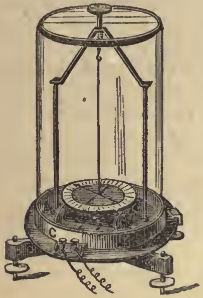
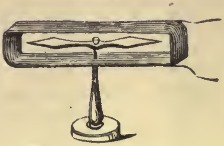


FIG. 43.



Galvanometers.

then be deflected towards his left. If the observer be above the needle his left is in one direction, but reversed if he observe from below. A current making a circuit of the needle increases its effect. A needle, then, placed within many coils of the same insulated wire can be deflected when the current is so weak that a single coil would fail to give any results. Galvanometers made sensitive by thousands of coils are termed long-coil galvanometers; those with fewer turns are short-coil galvanometers.

If the current be too strong for the instrument, it may be divided and the parts separately measured. The adjusting apparatus is called a shunt.

What is the rheostat?

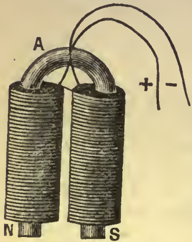
The rheostat is an instrument for measuring the resistance of an electric current. In principle it is some material of known resistance imposed in the path of a current. By using some adjustable apparatus, as coils of wire, the resistance can be lessened or increased. The longer the coil the greater its resistance, and, therefore, a length of wire can be adjusted so as totally to impede the current and thus to compute its resistance. Wheatstone's bridge is one of the most useful resistance-measurers.

What medical application have the galvanometer and the various resistance machines?

A sensitive galvanometer may be used to determine electric currents in the human body, and a rheostat or a similar contrivance to compare the resistance or conductivity of various tissues, a knowledge of which is important in physiology and therapeutics.

Explain the magnetic effects of electricity.

FIG. 44.



Electromagnet.

If a copper wire be insulated and coiled around a piece of *soft* iron (Fig. 44), and a current passed through it, the iron will become a magnet and remain one as long as the current flows. The iron will, however, cease to be a magnet if the current be interrupted. This magnet is, in all its properties, similar to the ordinary magnet, but is not permanent. Such a magnet is called the *electro-magnet.* Of the many forms existent, the usual one consists of two soft-iron cores, joined by an iron yoke, around each of which insulated wire is coiled. These pieces of iron may be magnetized and demagnetized at will by completing and interrupting the current.

What application has the electro-magnet?

Its applications are numerous. Nearly all electric apparatus owes its effectiveness to the fact that soft iron can be made a temporary magnet to attract the end of an iron lever from a position to which it returns by the aid of springs whenever the current is interrupted. Repeatedly making and breaking the circuit move the lever which sets the simple or intricate clock-work in operation. On the electro-magnet depend electric instruments such as the telegraph, telephone, electric bells, etc.

In the telegraph this clock-work either registers marks on paper or produces sounds. In either case the length and frequency of the marks or sounds indicate letters and words.

What is electro-magnetic induction?

It has been cited that a body charged with electricity has power to induce electricity in a second body when brought near to it. This is termed electro-static induction. Current electricity has its parallel in the current induced by placing a magnet in a spool-shaped coil of insulated wire. As shown by the galvanometer, this current in the wire is only temporary; it is again induced, but in the opposite direction, when the magnet is removed. If the magnet be moved back and forth in the coil, a series of alternating currents will be the result.

What is the induction coil?

It is a mechanism which makes induced currents available. It consists of a core of iron surrounded by a coil of wire connected with a galvanic cell. Outside of this coil of coarse wire well insulated is another coil of much finer wire, making many coils about the first or primary coil. The cell creates a current in the primary which induces a current in the secondary. It is, however, a temporary current. By making and breaking the connection between the primary coil and the cell, alternating currents are induced. The *soft*-iron core, which is usually a bundle of wires, becomes a magnet with each contact between the primary coil and cell, and, as such, is used to break repeatedly the circuit produced by the cell. This association of a magnet, cell, and coils is called the faradic battery. It is much used for the medical application of electricity.

Describe a dynamo-electric machine.

These machines consist of a permanent magnet and an electro-magnet, so arranged that one is stationary and the other adjusted to revolve on an axis and between the poles of the former. Many forms have been invented, in some of which the permanent magnet is stationary, while in others the electro-magnet remains stationary. In either case the varying relation between the two magnets is the same and productive of currents. By mechanism the current can be made to flow constantly in one direction, and the machine is termed a *constant current machine;* or it can be made to alternate in opposite directions, when it is called an *alternating current machine.* The power of the current depends upon the strength of the magnet; upon the length and number of turns in the wire; upon the speed of revolution, and upon the conductivity of the wire. Steam power is usually employed to revolve the magnets.

For what purposes are the dynamo-electric machines used?

They have innumerable uses for heating, lighting, electro-plating, electro-typing, etc., besides producing electricity for mechanical work, such as operating pumps, elevators. fans, lathes, and many other machines. The Edison and Brush dynamos are continuous current machines.

Name the systems for electric illumination.

Practically there are two systems—the arc light and the incandescent light systems.

Explain the arc system.

If the terminals of two electric wires leading from a powerful dynamo be brought near together, the current will continue to flow across this space and thus produce intense light, which is of short duration, because the heat generated melts the wire and widens the space beyond the traversing power of the current. It is therefore necessary to tip the ends of these wires with some refractory material and to regulate the intervening space by clock-work. Pencils made of carbon best answer for tips, although they waste away and need replenishing. The current always passes from the positive to the negative point, and in so doing carries particles of highly heated, luminous carbon, which either consume themselves or lodge on the negative point. These white-hot particles on their journey furnish light. The negative carbon is built up at the expense of the positive carbon, which is constantly being lessened.

Describe the incandescent light.

If a bit of line wire through which a strong current is passing be cut out, and a refractory non-conductor capable of luminous effects be substituted for it, the resistance thus introduced will convert electric energy into heat and produce a luminous link in the wire. To insure permanence and better results, this link is made into a loop or coil and hermetically sealed in a glass globe from which the air has been exhausted. This is to prevent oxidation or combustion, and thus arranged it generates but little heat, although its illuminating power is great. Platinum and bamboo carbon are used for the loop. These loops can be made of any size, and are serviceable not only in a general way, but for special purposes, such as illuminating cavities of the body—throat and nose. The chemical rays of the arc light are somewhat similar to those of the sun.

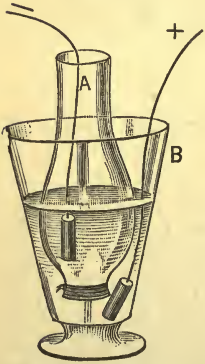
What application has electricity to chemistry?

In chemistry, electricity is frequently employed to reduce metals from their ores. It is often the most potent and competent agent available for this purpose. Metals which resist the action of economical chemicals or involve complex operations are often subjected to electric separation. Aluminium in considerable quantities is prepared by electricity.

Give an example of decomposition by electricity.

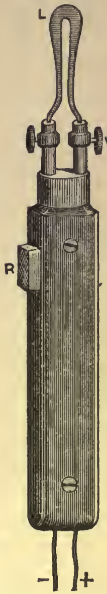
Take a vessel shaped like the chimney of a kerosene lamp, *A* (Fig. 45). Close the lower mouth with a layer of goldbeater's skin, tying it on firmly. Prepare a tolerably strong solution of sodium chloride; add to it sufficient red litmus water to give it a strong tint. Pour half into the vessel; let it rest in a goblet, *B*, and pour the other half into this. Pass into the former the platinum terminal of the cathode; into the latter plunge the anode. Make connection with the battery. Gas bubbles appear at both poles, but the liquids are prevented from intermingling by the intervening septum of goldbeater's skin. At the cathode, sodium is set free, which instantly attacking the water becomes converted into sodium oxide, and its alkaline reaction is exhibited by turning the red litmus blue. At the anode, chlorine is evolved, as shown by bleaching of the litmus. The sodium chloride has, therefore, undergone decomposition, the sodium appearing at the cathode and the chlorine at the anode.

FIG. 45.



Sodium chloride decomposed.

FIG. 46.



Galvanocautery holder.

What is electro-plating?

It is an electric process of applying a metallic coating to another metal, as silver-plating a spoon. The requisites for the process in this special case would be a tub or bath containing a solution of a silver salt; two bars, good conductors, laid across the bath, from one of which is suspended the spoon immersed in the solution, and from the other a sheet or plate of silver. The negative wire of a battery is connected to the rod suspending the spoon and the positive wire to the rod holding the silver. Electric action takes place in the solution and deposits silver over the surface of the spoon. To be copper-coated, an object would require a copper plate and a copper solution; or a gold plate and a gold solution for gold-plating.

How is electricity used as a cautery?

The apparatus consists of a platinum wire about one millimetre thick, bent into a close loop and flattened to form a knife-edge, *L* (Fig. 46). The current from two large cells sent through this readily raises it to a red heat. It is useful for drawing lines along the skin, to destroy granulations, to open abscesses, and to cauterize prolapsus recti. The current is turned on and off the wire by pressure of the thumb upon a button, *R*.

Other forms of the loop or snare are employed to remove enlarged tonsils, tumors in the nose, throat, and ears, and to cicatrize various fleshy parts.

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